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Standards of performance to control Volatile Organic Compounds (VOC) from new, modified, and reconstructed automobile and light-duty truck surface coating operations are being proposed under Section 111 of the Clean Air Act. This document contains information on automobile and light-duty truck surface coating operations and VOC Emission Control Technology, as well as a discussion of the selected emission limitations and the supporting data and the alternatives which were considered. Environmental and economic impact analyses of the proposed standards are also included.

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Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
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1. SUMMARY

1.1 PROPOSED STANDARDS

Standards of performance for automobile and light-duty truck surface coating operations have been proposed under Section 111 of the Clean Air Act. The proposed standards would limit emissions of volatile organic compounds (VOC) from new, modified, and reconstructed facilities. Volatile organic compounds are organic compounds which participate in atmospheric photochemical reactions or are measured by the proposed Reference Methods 24 (Candidates 1 and 2) and 25.

Numerical emission limits for each "affected facility" have been selected as follows:

> 0.10 kilogram of VOC (measured as mass of carbon) per liter of applied coating solids from each prime coat operation
>
> 0.84 kilogram of VOC (measured as mass of carbon) per liter of applied coating solids from each guide coat operation
>
> 0.84 kilogram of VOC (measured as mass of carbon) per liter of applied coating solids from each topcoat operation

These limits are based on the use of water-based coating materials in the prime coat, guide coat, and topcoat operations. Usually water-based prime coat is applied by electrodeposition (EDP). A transfer efficiency of 40 percent is assumed for spray application of these coatings. The emission limits may also be achieved by using add-on control devices, such as thermal or catalytic incineration, to reduce VOC from solvent-based coatings.

Reference Method 24 (Candidate 1), "Determination of Volatile Content (as Carbon) of Paint, Varnish, Lacquer, or Related Products," has been proposed in two forms - Candidate 1 and Candidate 2. Candidate 1 leads to a determination of VOC content expressed as the mass of carbon. Candidate 2 yields a determination of VOC content measured as mass of volatile organics. The decision as to which candidate will be used depends on the final format selected for the proposed standards. Reference Method 25, "Determination of Total Gaseous Nonmethane Organic Emissions," has been proposed as the test method to determine the percentage reduction of VOC emissions achieved by add-on control devices.

1.2 ENVIRONMENTAL, ENERGY, AND ECONOMIC IMPACTS

The VOC emissions from automobile and light-duty truck surface coating operations can be controlled by the use of coatings having a low organic solvent content, add-on controls, or a combination of the two. Low organic solvent coatings consist of water-based enamels, high solids enamels, and powder coatings. Add-on controls consist of such techniques as incineration and carbon adsorption.

1.2.1 Background

New Coatings. Water-based coating materials are applied either by conventional spraying or by EDP. In the EDP process the automobile or light-duty truck to be coated is dipped into a bath containing a dilute water solution of the coating material. When charges of opposite polarity are applied to the dip tank and vehicle, the coating material deposits on the latter. As the coating material deposits on the surface, it acts as an insulator between the bare metal surface and the EDP tank, thus limiting the film thickness which can be applied by EDP. Consequently, EDP is limited to application of prime coats, and spraying is used for guide coat and topcoat application of water-based coatings. Currently, nearly half of the domestic automobile assembly plants use EDP for prime coat application, but only two domestic plants use water-based coatings for guide coat and topcoat applications.

High solids coatings, which include coatings of 45 to 60 percent solids, are being developed by a number of companies. While high solids coatings have the potential for use in the automotive industry, there are problems which must be overcome. These coatings have a high working viscosity which makes them unsuitable for use in many existing application devices. There are also some problems with the finish produced by high solids coatings. Since the viscosity of the material is very high, it often produces an "orange peel," or uneven, surface. High solids coatings are also limited because metallic finishes cannot be applied. However, techniques such as heated application are being investigated to reduce these problems, and it is expected that by 1982, high solids coatings will be considered technically demonstrated for use in the automotive industry.

Powder coatings are a special class of high solids coatings that consist of solids only. They are applied by electrostatic spray and are being used on a limited basis for topcoating automobiles, both foreign and domestic. The use of powder coatings is severely limited, however, because metallic finishes cannot be applied using powder. As with other high solids coatings, research is continuing in the use of powder coatings for the automotive industry.

Add-on Controls. Incineration may be either thermal or catalytic. Thermal incineration has been used to control emissions from bake ovens in automobile and light-duty truck assembly plants because of the fairly low volume and high VOC concentration in the exhaust stream. These units normally achieve a VOC emissions reduction of over 90 percent. Thermal incinerators have not, however, been used for control of spray booth VOC emissions. Typically, the spray booth exhaust stream is a high volume stream (95,000 to 200,000 liters per second) very low in concentration of VOC (about 50 ppm). Thermal incineration of this exhaust stream would require a large amount of supplemental fuel, either oil or natural gas. There are, however, no technical problems with the use of thermal incineration.

Catalytic incineration permits lower incinerator operating temperatures and, therefore, requires about 50 percent less energy than thermal incineration. While catalytic incineration is not currently being employed in the automobile and light-duty truck industry for control of VOC emissions, there are no major technical problems which would preclude its use on bake oven exhaust gases. However, catalytic incineration requires the use of natural gas to preheat the exhaust gases since oil firing tends to foul the catalyst. With regard to spray booth emission control, the same considerations apply as in the case of thermal incineration (i.e., a high energy impact and requirement for use of natural gas, whose future availability for incinerator use is questionable).

Carbon adsorption has been used successfully to control VOC emissions in a number of small industrial applications. However, the ability of carbon adsorption to control VOC emissions from spray booths and bake ovens in automobile and light-duty truck surface coating operations is uncertain. The high volume/low VOC exhaust streams from spray booths would require carbon adsorption units much larger than any that have ever been built. Work is continuing, however, on efforts to apply carbon adsorption to the automotive industry, and it may become a demonstrated technology in the future.

Water-based coatings and incineration are two well-demonstrated and feasible techniques for controlling emissions of VOC from automobile and light-duty truck surface coating operations. Based upon the use of these two VOC emission control techniques, two regulatory options were evaluated. The two options are summarized in the following paragraphs. In both options, the prime coat is water-based and applied by EDP.

Regulatory Option I includes two alternatives which achieve essentially equivalent control of VOC emissions. Alternative A is based on the use of a water-based prime coat, guide coat, and topcoat. Alternative B is based on the use of water-based prime coat and a solvent-based guide coat and topcoat with incineration of the exhaust gas stream from the topcoat spray booth and bake oven to control emissions.

Regulatory Option II is based on the use of a water-based prime coat and a solvent-based guide coat and topcoat. In this option, the exhaust gas streams from both the guide coat and topcoat spray booths and bake ovens are incinerated to control emissions.

1.2.2 Impacts

The incremental impacts of the proposed standards would be determined by the final emission limitations adopted by the State Implementation Plans (SIPs) which are currently being revised. The impacts presented throughout this document were evaluated using the SIPs in existence at the end of 1978 as a basis. Standards based on Regulatory Option I would lead to a reduction in VOC emissions of about 80 percent, and standards based on Regulatory Option II would lead to a reduction in emissions of about 90 percent compared to VOC emissions from an automobile or light-duty truck assembly plant using solvent-based coatings with no add-on control devices. Growth projections indicate there will be four new automobile assembly plants constructed by 1983. Based on this assumption, it is estimated that by 1983 national emissions of VOC would be reduced by about 4,800 metric tons per year with standards based on Regulatory Option I, or about 5,400 metric tons per year with standards based on Regulatory Option II. Thus, both regulatory options would result in a significant reduction in emissions of VOC from automobile and light-duty truck surface coating operations.

With regard to the water pollution impact, standards of performance based on Regulatory Option II would have essentially no impact. Similarly, standards based on Regulatory Option I(B) would have no water pollution impact. Standards based on Regulatory Option I(A), however, would result in a slight increase in the chemical oxygen demand (COD) of wastewater being generated from automobile and light-duty truck assembly plants. However, the increase in COD under Regulatory Option I(A) would be small relative to current COD levels at plants meeting existing SIP's, and would not result in a significant increase in the water treatment requirements.

The solid waste impact of the proposed standards would be negligible. The volume of sludge generated from water-based coating operations is approximately the same as that generated from a solvent-based operation. The solid waste generated from solvent-based coatings, however, is very sticky, and equipment cleanup is more time consuming than for solvent-based coatings. Sludge from either type of system can be disposed of by conventional landfill procedures without leachate problems.

With regard to the energy impact, standards of performance based on Regulatory Option I(A) would increase the energy consumption of surface coating operations at a new automobile or light-duty truck assembly plant by the equivalent of about 18,000 barrels of fuel oil per year, representing an additional 25 percent over the current annual consumption rate. Regulatory Option I(B) would cause an increase of about 150 to 425 percent in energy consumption, equivalent to 100,000 to 300,000 barrels of the oil per year. Standards based on Regulatory Option II would result in an increase of 300 to 700 percent in energy consumption, representing an additional 200,000 to 500,000 barrels of fuel oil per year. The relatively high energy impact of standards based on Regulatory Option I(B) and Regulatory Option II is due to the large amount of incineration fuel needed, and the ranges reflect the difference between catalytic and thermal incineration.

In determining the economic impacts of the proposed standards, costs were estimated for applying each control option to the four new assembly lines which are expected to be built by 1983. Of these four lines, two are General Motors lines (one passenger car and one light-duty truck), one is a Ford light-duty truck line, and the other is a Chrysler passenger car line. In the absence of any air pollution regulations, General Motors plants would be designed to use solvent-based lacquer coatings in guide coat and topcoat; Ford, Chrysler, and all other manufacturers would use solvent-based enamels in guide coat and topcoat.

Capital costs for the four new facilities planned by 1983 would be increased by approximately $19 million as a result of the proposed standards. This incremental capital cost for control represents about 0.2 percent of the $10 billion planned for capital expenditures during the same time period. The corresponding annualized costs would be increased by approximately $9 million in 1983. The price of an automobile or light-duty truck manufactured at a new plant which complies with the proposed standards of performance would be increased by much less than 1 percent.

1.3 INFLATIONARY IMPACT

The projected economic impacts of each alternative control system are small, and the costs of the proposed standards of performance should not preclude future construction of coating lines. Effects on production of automobiles and light-duty trucks and on employment should be insignificant.

Total investment costs are projected to be approximately $19 million. The fifth-year annualized costs, including depreciation and interest, are estimated at approximately $9 million. The maximum anticipated unit price increase is much less than 1 percent. Therefore, the Agency feels that an economic impact analysis is not required.

Table 1-1. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS OF REGULATORY OPTIONS (ALTERNATIVES)

Administrative Action	Air Impact	Water Impact	Solid Waste Impact	Energy Impact	Noise Impact	Economic Impact
Proposed Standards	+2**	-1**	0	-2**	0	-1**
Regulatory Option I(B)	+2**	0	0	-3**	0	-2**
Regulatory Option II	+3**	0	0	-3**	0	-3**
No Standards	0	0	0	0	0	0

KEY

+ Beneficial Impact
- Adverse Impact

0 No Impact
1 Negligible Impact
2 Small Impact
3 Moderate Impact
4 Large Impact

* Short-Term Impact
** Long-Term Impact

2. INTRODUCTION

Standards of performance are proposed following a detailed investigation of air pollution control methods available to the affected industry and the impact of their costs on the industry. This document summarizes the information obtained from such a study. Its purpose is to explain in detail the background and basis of the proposed standards and to facilitate analysis of the proposed standards by interested persons, including those who may not be familiar with the many technical aspects of the industry.

2.1 AUTHORITY FOR THE STANDARDS

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, hereafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect " . . . the degree of emission limitation achievable through the application of the best technological system of continuous emission reduction . . . the Administrator determines has been adequately demonstrated." The Act also provides that the cost of achieving the necessary emission reduction, the nonair quality health and environmental impacts, and the energy requirements all be taken into account in establishing standards of performance. The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the FEDERAL REGISTER.

The 1977 amendments to the Act altered or added numerous provisions which apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources which have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

   25 percent of the listed categories by August 7, 1980
   75 percent of the listed categories by August 7, 1981
   100 percent of the listed categories by August 7, 1982

   A Governor of a State may apply to the Administrator to add a category which is not on the list or to revise a standard of performance.
2. EPA is required to review the standards of performance every 4 years and, if appropriate, to revise them.
3. EPA is authorized to promulgate a design, equipment, work practice, or operational standard when an emission standard is not feasible.
4. The term "standards of performance" is redefined and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low-polluting or nonpolluting process or operation.
5. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations in which some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting if pollution ceilings are reduced in the future. Fourth, certain types of standards for coal burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potential is high. Congress does not intend for new source performance standards to contribute to these problems. Fifth, the standards setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the national ambient air quality standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area which falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas be subject to best available control technology. The term "best available control technology" (BACT), as defined in the Act, means ". . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of best available control technology result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Section 111 or 112 of this Act" (Section 169(3)).

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases, physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling.

The nature of the emissions--high concentrations for short periods during filling and low concentrations for longer periods during storage--and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, Section 111(j) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require, or an equivalent reduction at lower economic, energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to public health, welfare or safety; (4) the Governor of the State where the source is located consents; and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards, with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Administrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such a list if in his judgment it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants which are emitted by stationary sources. Source categories which emit these pollutants have been evaluated and ranked by a process involving such factors as: (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might be required from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented, in a preselected future year, by standards of performance for the source category. Sources for which new source performance standards were promulgated, or were under development during 1977 or earlier, have been selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are:

1. The quality of air pollutant emissions which each such category will emit, or will be designed to emit;
2. The extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and

3. The mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to in Section 2.1 of this chapter. In some cases, it may not be feasible to immediately develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process, the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may be insignificant or very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there may be no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standard.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must: (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, nonair quality health and environmental impacts, and energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best technological system of continuous emission reduction which has been adequately demonstrated. The legislative history of Section 111 and various court decisions make it clear that the Administrator's judgment of what is adequately demonstrated is not limited to systems in actual routine use. The search may include a technical assessment of control systems which have been adequately demonstrated but for which there is limited operation experience. In most cases, determination of the ". . . degree of emission reduction achievable . . ." is based on results of tests of emissions from well-controlled existing sources. At times, this has required the investigation and measurement of emissions from control systems found in other industrialized countries that have developed more effective systems of control than those available in the United States.

Since the best demonstrated systems of emission reduction may not be in widespread use, the data base upon which standards are developed may be somewhat limited. Test data on existing well-controlled sources are obvious starting points in developing emission limits for new sources. However, since the control of existing sources generally represents retrofit technology or was originally designed to meet an existing State or local regulation, new sources may be able to meet more stringent emission standards. Accordingly, other information must be considered before a judgment can be made as to the level at which the emission standard should be set.

A process for the development of a standard has evolved which takes into account the following considerations:

1. Emissions from existing well-controlled sources as measured.
2. Emissions data from such sources which are assessed with consideration of such factors as (a) the representativeness of the tested source in regard to feedstock, operation, size, age, etc.; (b) age and maintenance of the control equipment tested; (c) design uncertainties of control equipment being considered; and (d) the degree of uncertainty that new sources will be able to achieve similar levels of control.
3. Information from pilot and prototype installations, guarantees by vendors of control equipment, unconstructed but contracted projects, foreign technology, and published literature are also considered during the standard development process. This is especially important for sources for which "emerging" technology appears to be a significant alternative.

4. Where possible, standards are developed which permit the use of more than one control technique or licensed process.
5. Where possible, standards are developed to encourage or permit the use of process modifications or new processes rather than "add-on" systems as methods of air pollution control.
6. In appropriate cases, standards are developed to permit the use of systems capable of controlling more than one pollutant. As an example, a scrubber can remove both gaseous and particulate emissions, but an electrostatic precipitator is specific to particulate matter.
7. Where appropriate, standards for visible emissions are developed in conjunction with concentration/mass emission standards. The opacity standard is established at a level that will require proper operation and maintenance of the emission control system installed to meet the concentration/mass standard on a day-to-day basis. In some cases, however, it is not possible to develop concentration/mass standards, such as with fugitive sources of emissions. In these cases, only opacity standards may be developed to limit emissions.

2.4 CONSIDERATION OF COSTS

Among the requirements of Section 317 of the Act is an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of:

(1) the costs of compliance with the regulation and standard, including the extent to which the cost of compliance varies depending on

the effective date of the standard or regulation and the development of less expensive or more efficient methods of compliance;

(2) the potential inflationary/recessionary effects of the standard or regulation;

(3) the effects on competition of the standard or regulation with respect to small business;

(4) the effects of the standard or regulation on consumer cost; and

(5) the effects of the standard or regulation on energy use.

Section 317 requires that the economic impact assessment be as extensive as practicable, taking into account the time and resources available to EPA.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical existing State control regulations. An incremental approach is taken since both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the impact upon the industry resulting from the cost differential that exists between a standard of performance and the typical State standard.

The costs for control of air pollutants are not the only costs considered. Total environmental costs for control of water pollutants as well as air pollutants are analyzed wherever possible. A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made. It is also essential to know the capital requirements placed on plants in the absence of Federal standards of performance so that the additional capital requirements necessitated by these standards can be placed in the proper perspective. Finally, it is necessary to recognize any constraints on capital availability within an industry, as this factor also influences the ability of new plants to generate the capital required for installation of additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that ". . . the best system of emission reduction, . . . require(s) the Administrator to take into account counterproductive environmental effects of a proposed standard, as well as economic costs to the industry . . ." On this basis, therefore, the courts ". . . established a narrow exemption from NEPA for EPA determination under Section 111."

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "no action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969" (15 U.S.C. 793(c)(1)).

The Agency has concluded, however, that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, while not legally required by Section 102(2)(c) of NEPA, environmental impact statements will be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section is included in this document which is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are identified and discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source becomes a new source if the source is modified or reconstructed. Both modification and reconstruction are defined in amendments to the general provisions of

Subpart A of 40 CFR Part 60 which were promulgated in the FEDERAL REGISTER on December 16, 1975 (40 FR 58416). Any physical or operational change to an existing facility which results in an increase in the emission rate of any pollutant for which a standard applies is considered a modification. Reconstruction, on the other hand, means the replacement of components of an existing facility to the extent that the fixed capital cost exceeds 50 percent of the cost of constructing a comparable entirely new source and that it be technically and economically feasible to meet the applicable standard. In such cases, reconstruction is equivalent to new construction.

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under Section 111(d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the act provides that the Administrator ". . . shall, at least every four years, review and, if appropriate, revise . . ." the standards. Revisions are made to ensure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. THE AUTOMOBILE AND LIGHT-DUTY TRUCK INDUSTRY

3.1 GENERAL DESCRIPTION

3.1.1 Automobile Industry

The automobile* industry is the largest manufacturing industry in the United States. Motor vehicle and allied industries account for one-sixth of the Gross National Product.[1] In 1977, the four major automobile manufacturing companies--General Motors Corporation, Ford Motor Company, Chrysler Corporation, and American Motors Corporation--had combined sales of $111 billion. Any significant change in the automobile industry affects the entire economy of the United States. According to the U.S. Department of Commerce, for every 10 workers producing automobiles, trucks, and parts, 15 additional people are employed in industries that provide the materials and manufacture components for these industries. Employment figures for the automobile industry are given in Table 3-1.

Among the four automobile manufacturers, General Motors accounts for the largest portion, 57 percent, of the total market. Table 3-2 shows domestic production by manufacturer. Automobile assembly plants are located in 19 states and 43 cities, as shown in Table 3-3. However, over 32 percent of all automobiles produced in the U.S. are manufactured in Michigan. Table 3-4 summarizes the automobile assembly plants by manufacturer, location, and make of automobile.

On the average, automobile assembly plants operate approximately 4000 hours per year at production rates averaging more than 45 vehicles per hour for

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*The terms "automobile," "passenger car," and "car" are used interchangeably throughout this report.

Table 3-1. DIRECT EMPLOYMENT IN THE PRODUCTION OF AUTOMOBILES

1967	341,000
1971	382,000
1972	412,000
1973	450,000
1974	350,000
1975	380,000
1976 (Est.)	390,000

Table 3-2. SHARE OF TOTAL U.S. PRODUCTION[2,3]

Make	1967	1972	1977
	New Car Registration by Company in U.S.		
American Motors	237,785	301,973	181,433
Chrysler Corp.	1,341,392	1,466,141	1,181,140
Ford Motor Co.	1,851,440	2,549,296	2,431,126
General Motors Corp.	4,139,037	4,635,656	4,985,150
Miscellaneous	787,767	5,326	5,316
12-Month Total	8,357,421	8,958,392	8,784,165

Production Summary:

1974 Total U.S. Production = 7,324,504

1975 Total U.S. Production = 6,716,951

1976 Total U.S. Production = 8,497,893

1977 Total U.S. Production = 8,784,165

Table 3-3. AUTOMOBILE ASSEMBLY PLANT PRODUCTION

(Model Year 1977)[2]

State	City	Percentage	Units
CALIFORNIA	(Total)	8.1	740,492
	Fremont	1.8	164,216
	Los Angeles	1.4	128,143
	San Jose	0.7	59,744
	South Gate	1.4	131,233
	Van Nuys	2.8	257,156
DELAWARE	(Total)	4.0	363,202
	Newark	2.5	226,435
	Wilmington	1.5	136,767
FLORIDA	(Total)		-
	Sebring		-
GEORGIA	(Total)	6.6	595,926
	Atlanta	2.0	186,130
	Doraville	2.7	241,423
	Lakewood	1.9	168,373
ILLINOIS	(Total)	4.5	409,062
	Belvidere	1.9	173,178
	Chicago	2.6	235,884
KANSAS	(Total)	2.9	267,110
	Fairfax	2.9	267,110
KENTUCKY	(Total)	1.1	101,057
	Louisville	1.1	101,057
MARYLAND	(Total)	2.7	241,171
	Baltimore	2.7	241,171
MASSACHUSETTS	(Total)	1.5	135,776
	Framingham	1.5	135,776
MICHIGAN	(Total)	32.3	2,948,759
	Dearborn	1.4	131,016
	Detroit	6.4	587,342
	Flint	4.6	416,459
	Hamtramck	4.2	379,562
	Kalamazoo		-
	Lansing	4.4	404,000
	Pontiac	3.6	326,231
	Wayne	3.0	273,150
	Willow Run	2.8	255,078
	Wixom	1.9	175,921
MINNESOTA	(Total)	1.3	115,464
	Twin Cities	1.3	115,464

Table 3-3. (Continued)

State	City	Percentage	Units
MISSOURI	(Total)	11.1	1,010,786
	Kansas City	1.0	93,946
	Leeds	2.8	252,119
	St. Louis	7.3	664,721
NEW JERSEY	(Total)	6.6	596,791
	Linden	2.7	243,455
	Mahwah	2.9	260,560
	Metuchen	1.0	92,776
NEW YORK	(Total)	2.5	230,894
	Tarrytown	2.5	230,894
OHIO	(Total)	7.3	660,101
	Avon Lake	0.4	36,136
	Lorain	2.7	241,017
	Lordstown	1.8	162,029
	Norwood	2.4	220,919
TEXAS	(Total)	2.5	230,371
	Arlington	2.5	230,371
WISCONSIN	(Total)	5.0	457,581
	Janesville	3.0	275,576
	Kenosha	2.0	182,005
UNITED STATES	TOTAL	100.0	9,104,543

Table 3-4. AUTOMOBILE ASSEMBLY PLANTS

(Model Year 1977)

Manufacturer	Location	Make of Automobile
American Motors	Kenosha, Wisconsin	Hornet, Gremlin, Pacer, Matador
Chrysler Corp.	Belvidere, Illinois	Gran Fury, Royal Monaco, Chrysler
	Hamtramck, Michigan	Volare, Aspen
	Jefferson Ave., Detroit	Chrysler
	Lynch Rd., Detroit	Monaco, Fury
	Newark, Delaware	Volare, Aspen
	St. Louis, Missouri	Diplomat, LeBaron
	Wyoming, Michigan	Voyager, Sportsman, Volare, Aspen Export
Ford Motor Co.	Atlanta, Georgia	LTD II, Cougar/XR7
	Avon Lake, Ohio	Club Wagon
	Chicago, Illinois	Thunderbird
	Dearborn, Michigan	Mustang II
	Kansas City, Missouri	Maverick, Comet
	Lorain, Ohio	Cougar, LTD II
	Los Angeles, Calif.	LTD, Thunderbird
	Louisville, Kentucky	LTD
	Mahwah, New Jersey	Granada, Monarch
	Metuchen, New Jersey	Pinto, Bobcat
	St. Louis, Missouri	Mercury
	San Jose, California	Pinto, Mustang II, Bobcat
	Twin Cities, Minnesota	LTD
	Wayne, Michigan	Granada, Monarch, Versailles
	Wixom, Michigan	Lincoln, Mark V
General Motors Corp.	Arlington, Texas	Chevelle, Monte Carlo, Cutlass
	Baltimore, Maryland	Monte Carlo, Chevelle, Century, LeMans
	Detroit, Michigan	Cadillac, Eldorado, Seville
	Doraville, Georgia	Monte Carlo, Cutlass, Chevelle
	Fairfax, Kansas	Pontiac, Oldsmobile 88, Le Sabre
	Flint, Michigan	Buick, Century, Riviera
	Framingham, Mass.	Century, Cutlass
	Fremont, California	Monte Carlo, Century, Chevelle
	Janesville, Wisconsin	Chevrolet
	Lakewood, Georgia	Grand Prix, LeMans
	Lansing, Michigan	Oldsmobile, Cutlass, Toronado
	Leeds, Missouri	Monte Carlo, Nova, Skylark, Chevelle
	Linden, New Jersey	Cadillac, Oldsmobile, Buick
	Lordstown, Ohio	Sportvan, Sunbird, Monza, Vega, Astre
	Norwood, Ohio	Camaro, Firebird
	Pontiac, Michigan	Pontiac, LeMans, Grand Prix
	St. Louis, Missouri	Chevrolet, Corvette
	South Gate, Calif.	Chevrolet, Le Sabre, Oldsmobile 88
	Tarrytown, New York	Nova, Skylark, Ventura
	Van Nuys, California	Camaro, Firebird
	Willow Run, Michigan	Nova, Omega, Ventura, Skylark
	Wilmington, Delaware	Chevette
Checker Motors	Kalamazoo, Michigan	Checker
Sebring-Vanguard	Sebring, Florida	CitiCar
Volkswagen	New Stanton, Pa.	Rabbit

midsized passenger cars. In 1973, production of automobiles was 9.7 million, a 10 percent increase over 1972. Production of cars decreased considerably to 7.3 million in 1974 and 6.7 million in 1975. The major factor that brought about the decline in production was the serious shortage of gasoline and diesel fuel which developed at the end of 1973. Consequently, consumers began seeking small economical models, which were not yet available in the domestic market. Many American assembly plants producing large cars were converted to production of compact and subcompact models. As a result, plants had to close down; production fell sharply; and at one time there were nearly 150,000 auto workers out of work.

Following this decrease, an upward trend occurred in 1976, with production reaching the level of 8.6 million cars. The increase can be attributed first to the economic recovery during 1976 which allowed higher automobile sales. Secondly, a wide range of sizes--subcompacts, compacts, intermediate, and full-sized automobiles--became available. There is now evidence of down-sizing with each car size category. According to product mix plans through 1980, demand for domestic new cars is expected to be nearly constant over the next 4 years, with 1980 sales projected at 10,400,000 units, as shown in Figure 3-1.[4]

Sales of imported cars, which reached a peak of 18.4 percent of the U.S. market in 1975, have held fairly steady over the last several years with minor fluctuations. Several foreign car manufacturers plan to produce cars in the United States. Volkswagen is already producing cars for sale in America at its new plant in New Stanton, Pennsylvania.

3.1.2 Truck Industry

The truck industry manufactures a wide range of vehicles designed for personal and commercial applications. Different models of vehicles are

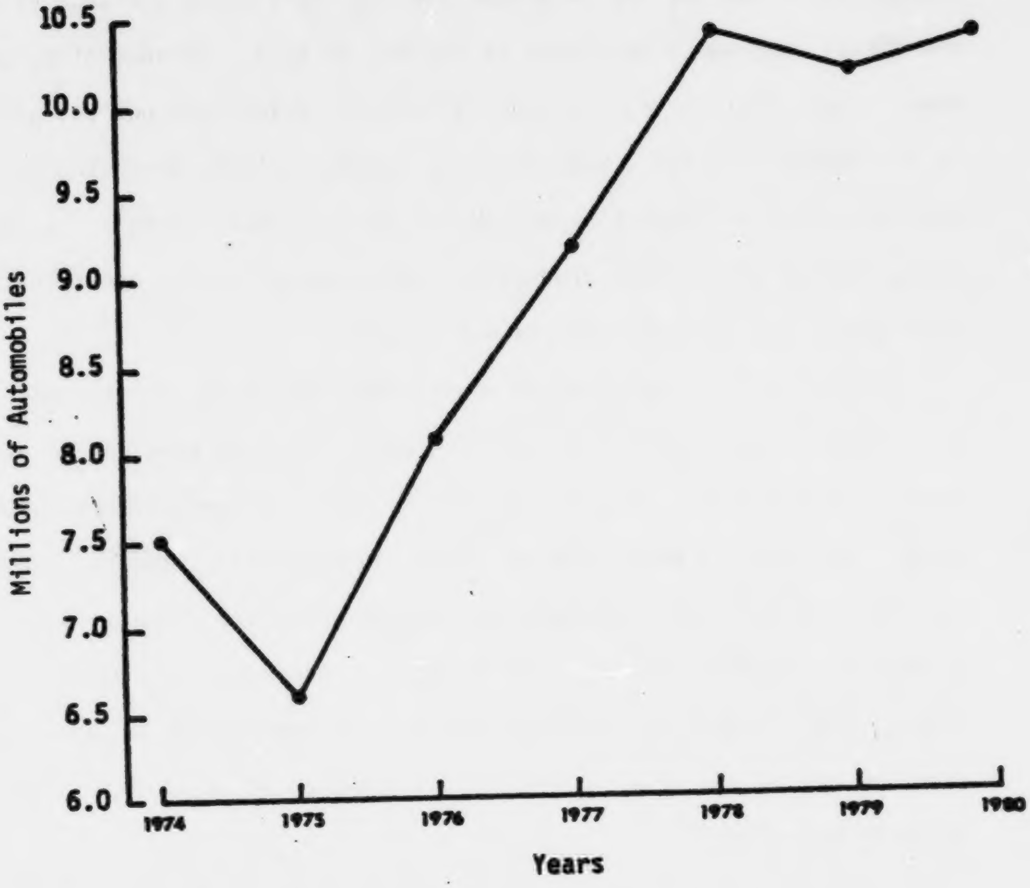

Figure 3.1 Automobile production trends.

classified by gross vehicle weight (GVW) and body type, as summarized in Table 3-5.

Almost 39 percent of the total production is comprised of vehicles with GVW of under 6,000 pounds, and about 75 percent of the total production consists of trucks with less than 8,500 pounds GVW. The term "light-duty truck" as used in this study indicates all vehicles with ratings of 8,500 pounds or less GVW. Thirty-five percent of all light-duty trucks are produced in Michigan. The remaining 65 percent are made in other states. Table 3-6 shows light-duty truck assembly locations in cities and states. Table 3-7 summarizes the light-duty truck assembly plants by manufacturer and location.

As in the automobile industry, the truck industry has been affected by recession in recent years. After the record production of 3,007,495 units in 1973, production slackened in 1974 and 1975. In 1976, however, production of trucks reached 3,015,000 units, and production in 1977 was 3,433,569 units. The major factors contributing to this growth were the overall economic growth, the new popularity of light-duty trucks and vans for personal use, and the improved availability of gasoline.

Assuming that another petroleum embargo does not occur and the improvement in the general economy continues as forecast, the annual growth rate is expected to be 4 percent per annum until 1980. A modest growth of 1 percent per annum is projected for 1980 to 1985.[4] As with the automobile industry, however, the demand for light-duty trucks will be influenced by monetary policy, fiscal policy, and other economic developments.

General Motors as a total entity again dominated the light-duty truck market with 45 percent of the total production in 1975. Light-duty truck production by model is shown in Table 3-8.

TABLE 3-5. 1975 U.S. TRUCK AND BUS FACTORY SALES BY BODY TYPES AND GROSS VEHICLE WEIGHT, POUNDS.

Body Type	6,000 and Less	6,001-10,000	10,001-14,000	14,001-16,000	16,001-19,50C	19,501-26,000	26,001-33,000	Over 33,000	Total
Pickup	1,036,438	901,278	-	-	-	-	-	-	1,937,716
General Utility	100,797	193,836	-	-	-	-	-	-	294,633
Van	185,610	341,002	-	-	-	-	-	-	526,612
Multi-Stop	-	36,326	18,014	1,221	697	-	-	-	56,258
Station Wagon (on truck chassis)	6	139,897	-	-	-	-	-	-	139,903
Buses (including school bus chassis)	-	-	-	-	126	29,173	545	1,429	31,273
Other body types	2,855	110,722	2,274	-	7,065	145,083	30,057	155,884	453,940
TOTAL	1,325,706	1,723,061	20,288	1,221	7,888	174,256	30,602	157,313	3,440,335

Table 3-6. LIGHT-DUTY TRUCK ASSEMBLY PLANTS

(Model Year 1975)[4,5,6]

State	City	Percentage	Units
CALIFORNIA	(Total)	8	130,829
	Fremont	3	53,000
	San Jose	5	77,829
GEORGIA	(Total)	4	61,925
	Atlanta	1	13,228
	Lakewood	3	48,697
KENTUCKY	(Total)	9	153,404
	Louisville	9	153,404
MARYLAND	(Total)	4	72,175
	Baltimore	4	72,175
MICHIGAN	(Total)	35	601,456
	Detroit	1	10,543
	Flint	14	250,050
	Warren	12	212,033
	Wayne	8	128,830
MISSOURI	(Total)	10	181,377
	Kansas City	4	67,946
	St. Louis	6	113,431
NEW JERSEY	(Total)	3	42,925
	Mahwah	3	42,925
OHIO	(Total)	20	357,502
	Avon Lake	9	143,895
	Lordstown	6	102,763
	Toledo	3	110,844
VIRGINIA	(Total)	3	54,777
	Norfolk	3	54,777
WISCONSIN	(Total)	4	62,153
	Janesville	4	62,153
UNITED STATES	TOTAL	100	1,718,523

Table 3-7. LIGHT-DUTY TRUCK ASSEMBLY PLANT LOCATIONS

(Model Year 1978)[6]

Manufacturer	Location
Chrysler Corp.	Warren, Michigan St. Louis, Missouri
Ford Motor Co.	Atlanta, Georgia Kansas City, Missouri Lorain, Ohio Louisville, Kentucky Mahwah, New Jersey Wayne, Michigan Norfolk, Virginia San Jose, California Twin Cities, Minnesota
General Motors Corp.	Baltimore, Maryland Detroit, Michigan Flint, Michigan Fremont, California Janesville, Wisconsin Lakewood, Georgia Lordstown, Ohio Pontiac, Michigan St. Louis, Missouri
Jeep	Toledo, Ohio
International Harvester	Fort Wayne, Indiana

Table 3-8. ESTIMATED LIGHT-DUTY TRUCK PRODUCTION[4,6,7]

Make	1974	1975
Chevrolet	724,052	624,061
Dodge	309,810	270,926
Ford	687,788	493,182
General Motors	138,625	182,954
International Scout	77,411	32,772
Jeep	114,132	106,704
TOTAL	2,051,818	1,656,599

3.2 PROCESSES OR FACILITIES AND THEIR EMISSIONS

3.2.1 The Basic Processes - Automobile Industry

3.2.1.1 General

The finishing process of an automobile body is a multistep operation carried out on a conveyor system known as the assembly line. Such a line operates at a speed of 9 to 25 feet per minute and generally produces 30 to 70 units per hour. The plant may operate up to three 8-hour shifts per day. Usually the third shift is used for cleanup and maintenance. Plants usually stop production for several weeks during the summer season for inventory and model changeover.

Although finishing processes vary from plant to plant, they have some common characteristics. Major successive steps of such processes are given below:

- Solvent wipe*
- Phosphating treatment
- Application of primer coat
- Curing of the primer coat
- Application of guide coat
- Curing of guide coat
- Application of the topcoat(s)
- Curing of the topcoat(s)
- Paint touchup operations

A process diagram of these consecutive steps of the automobile finishing process is presented in Figure 3-2. These steps are explained in more detail in Sections 3.2.1.2 through 3.2.1.4 of this document. Minimal

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*The term "solvent" in this document means organic solvent.

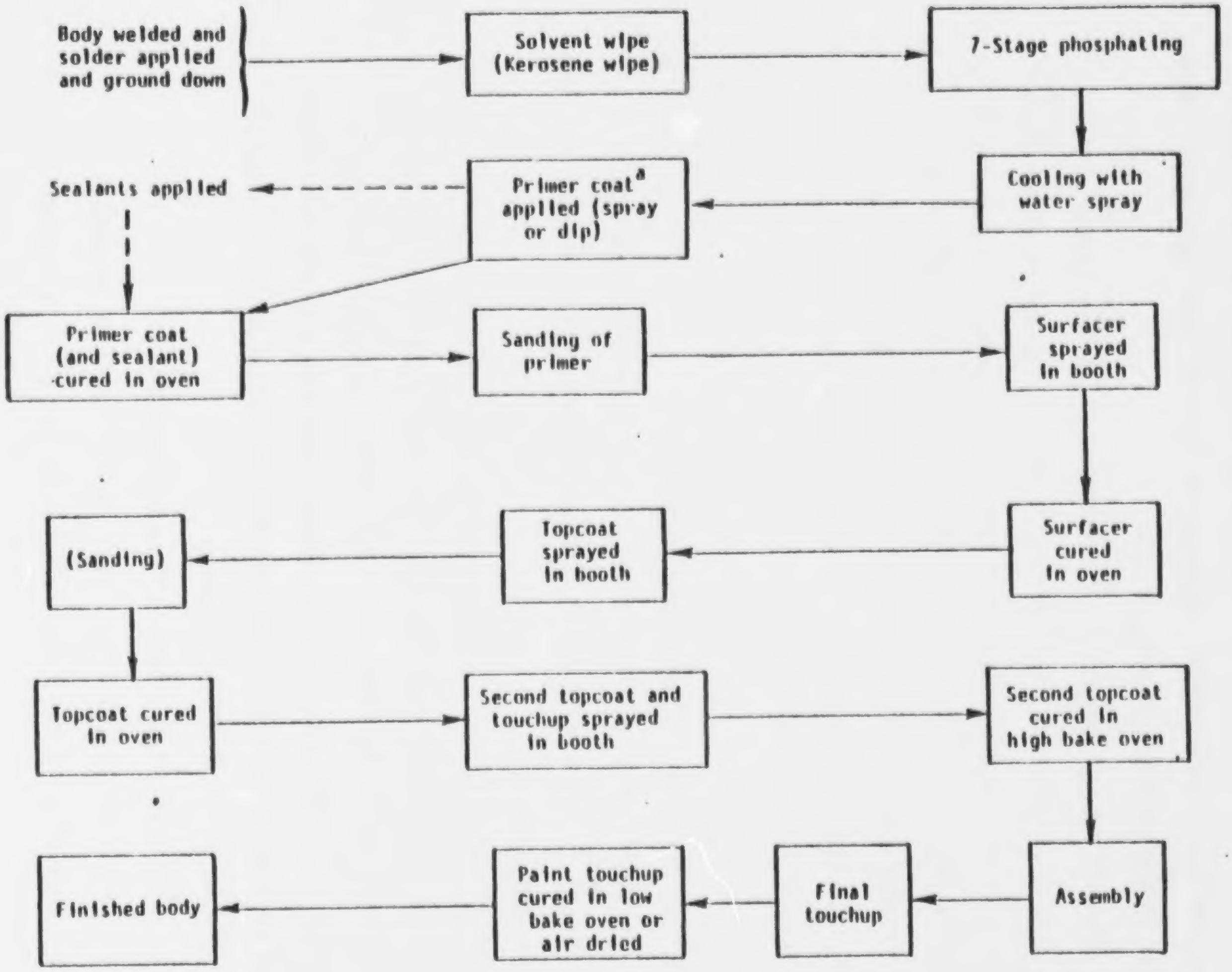
Body welded and solder applied and ground down
Solvent wipe (Kerosene wipe)
7-Stage phosphating
Cooling with water spray
Primer coat[a] applied (spray or dip)
Sealants applied
Primer coat (and sealant) cured in oven
Sanding of primer
Surfacer sprayed in booth
Surfacer cured in oven
Topcoat sprayed in booth
(Sanding)
Topcoat cured in oven
Second topcoat and touchup sprayed in booth
Second topcoat cured in high bake oven
Assembly
Final touchup
Paint touchup cured in low bake oven or air dried
Finished body

Figure 3-2. Traditional surface coating operations of an automobile and light duty truck assembly line.

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[a] Solvent-based primers are applied by spraying in booth; water-based primers are applied in a dip tank. Solvent-based primers are applied on an oven-dried body; water-based primers are applied on a wet body.

sanding may occur at various points of the surface coating operation, depending on the manufacturer. Application of sealants generally occurs after the primer application; sealants are usually cured together with the primer in the primer coat oven.

Touchup coating operations are conducted at various stages of the application of the topcoat(s) to yield a uniform appearance of the coated area. High bake touchup coating is performed prior to attachment of heat sensitive materials and is cured in a high temperature oven. Final, or low bake, repair generally uses a highly catalyzed air-drying coating. Air-drying coatings are required, since at this stage heat-sensitive plastics and rubber automotive parts have been built into the automobile, and the vehicle can only tolerate a low bake temperature.

3.2.1.2 Preparation of Metal Prior to Coating

The automobile body is assembled from a number of welded metal sections. The body and the parts that are coated all pass through the same metal preparation process.

First, surfaces are wiped with solvent to eliminate traces of oil and grease. Second, a phosphating process prepares surfaces for the primer application. Since iron and steel rust readily, phosphate treatment is necessary to prevent such rusting. Phosphating also improves the adhesion of the coating to the metal. The phosphating process occurs in a multi-stage washer in the following sequence:

1. Alkaline cleaner wash - 20 to 120 seconds
2. First hot water rinse - 60°C (140°F) - 5 to 30 seconds
3. Second hot water rinse - 60°C (140°F) - 5 to 30 seconds

4. Phosphating with zinc or iron acid phosphate - 15 seconds
5. Water rinse, ambient - 5 to 30 seconds
6. Dilute chromic acid rinse - 5 to 30 seconds
7. Deionized water rinse - 5 to 60 seconds

The parts and bodies pass through a water spray cooling process and, if solvent-based primer is to be applied, they are then oven dried.

3.2.1.3 Primer Coating

A primer is applied prior to the topcoat to protect the metal surface from corrosion and to ensure good adhesion of the topcoat. Figure 3-3, a flow diagram, shows process steps of both solvent-based primer and topcoat applications. Approximately half of all finishing processes use solvent-based primers and employ spray application. The rest use water-based primers.

Water-based primer is most often applied in an electrodeposition (EDP) bath. The composition of the bath is about 5 to 15 percent solids, 2 to 10 percent solvent, with the remaining portion being water. The solvents used are typically organic compounds of higher molecular weight, such as ethylene glycol monobutyl ether. When EDP is used, a guide coat (also called a primer surfacer) is applied between the primer and the topcoat. This guide coat can be either solvent-based or water-based. Guide coat and EDP are described in more detail in Chapter 4, Emission Control Techniques.

Solvent-based primer is applied by a combination of manual and automatic spraying. Solvent emissions for solvent-based primer application were derived from information collected from automobile manufacturers. Average solvent emissions were calculated to be 5.71 liters per vehicle for the primer application. Assuming that a car production line operates at a production rate of 55 cars per hour and two (8-hour) shifts per day,

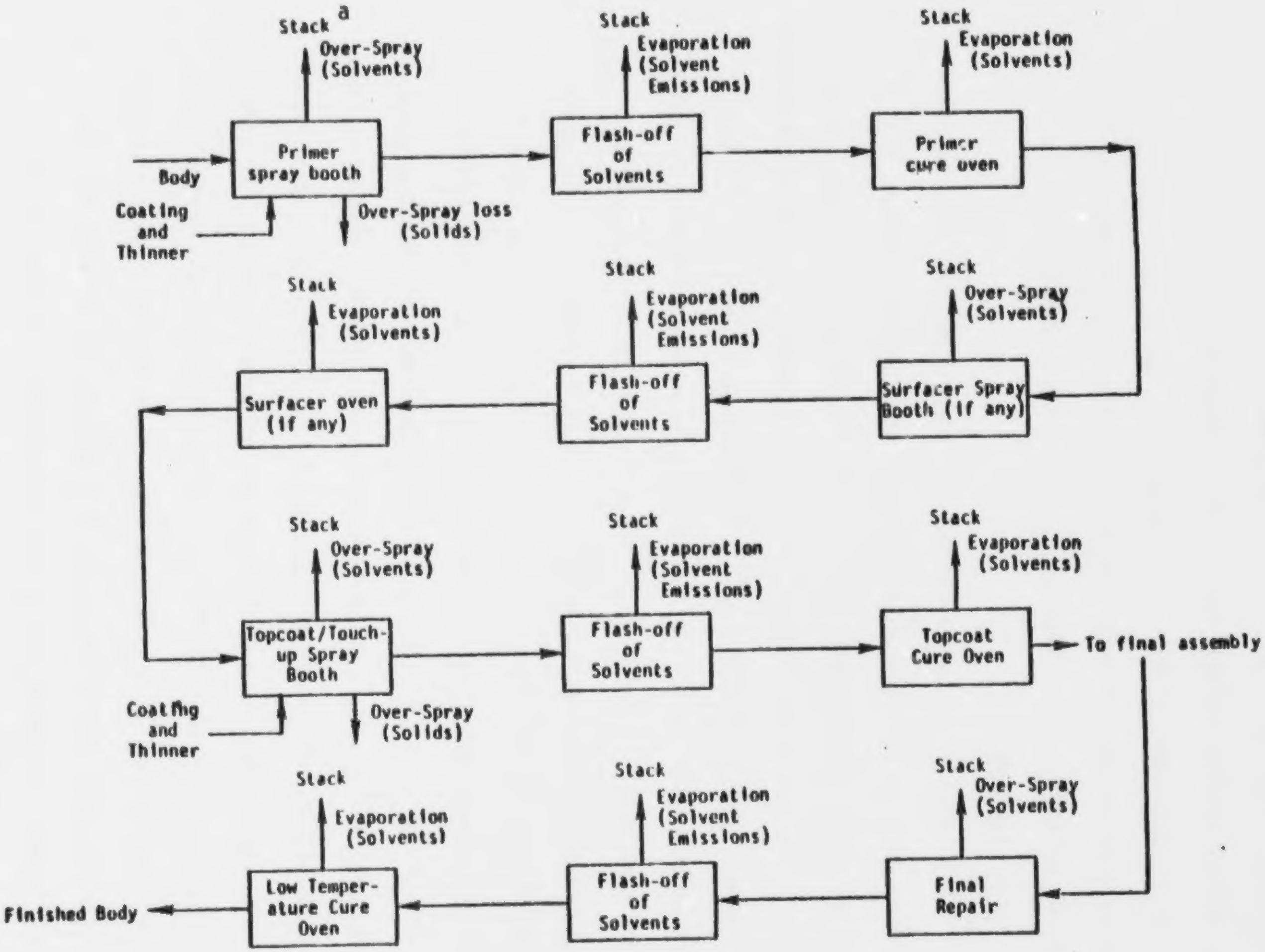
Stack a
Over-Spray (Solvents)
Body
Primer spray booth
Coating and Thinner
Over-Spray loss (Solids)
Stack
Evaporation (Solvent Emissions)
Flash-off of Solvents
Stack
Evaporation (Solvents)
Primer cure oven
Stack
Evaporation (Solvents)
Surfacer oven (if any)
Stack
Evaporation (Solvent Emissions)
Flash-off of Solvents
Stack
Over-Spray (Solvents)
Surfacer Spray Booth (if any)
Stack
Over-Spray (Solvents)
Topcoat/Touch-up Spray Booth
Coating and Thinner
Over-Spray (Solids)
Stack
Evaporation (Solvent Emissions)
Flash-off of Solvents
Stack
Evaporation (Solvents)
Topcoat Cure Oven
To final assembly
Stack
Evaporation (Solvents)
Low Temperature Cure Oven
Finished Body
Stack
Evaporation (Solvent Emissions)
Flash-off of Solvents
Stack
Over-Spray (Solvents)
Final Repair

Figure 3-3. Flow Diagram - Application of solvent-based primer and topcoat - automobile and light duty truck bodies.

[a] Stacks may be used for specific single operations or several operations may be combined and exhausted through a single stack.

Note: The only emission controlled areas of the process are the spray booths and cure ovens.

880 cars are produced daily. Approximately 4,218 kilograms of solvent (basis: density of 0.839 kg/liter) are therefore discharged daily from the primer application process.

Yearly energy requirements for solvent-based primer application and for EDP primer application are tabulated in Table 3-9 for a typical production line. A material balance for a typical 24 volume percent solvent-based primer is shown in Table 3-10, which includes the discharge of emissions at different steps in the process. Discharge of solvents to the atmosphere in the spray primer application is estimated as follows: 88 percent loss during application and 12 percent loss during oven drying of the coating. The information presented is from industrial surveys, 43 percent is used as a representative transfer efficiency. A material balance is not presented for an EDP prime system since virtually all solids are transferred to the vehicle and VOC emissions are very low because the coating is a water-based material.

3.2.1.4 Solvent-based Topcoat

The solvent-based topcoat is generally applied by a combination of manual and automatic sprays. Average percent solids content in the paint is in the range of 24 to 33 percent volume for solvent-based topcoat enamel type automotive finish, and 12 to 18 percent volume for solvent-based topcoat lacquer type automotive finish. A material balance for solvent-based enamel topcoat application is shown in Table 3-11.

Because of the time that the body is in the spray booth, 85 to 90 percent of the solvent evaporates in the booth and its flash-off area.[8] Solvent emissions vary with each automobile plant, depending mainly on the number of units produced daily, the surface area of each unit, and the

Table 3-9. ENERGY BALANCES OF PRIME COAT APPLICATIONS FOR AUTOMOBILES

Coating	Application[a] (10^6 Btu/hr[b])	Cure (10^6 Btu/hr[b])	Total
Solvent-based Spray Primer	15,167	76,187	91,354
EDP Primer	58,223	73,723	131,946

[a] This amount is highly dependent on climate since outside air must be heated to comfortable temperatures. The amount of heat required for this can be twice that required for curing.

[b] Annual energy consumption calculations were based on 211,200 cars produced per year, derived as follows: (1) Production rate - 55 cars/hr; (2) Time - 2 shifts (8 hrs/shift) per day, 240 days/yr; or 55 cars/hr x 3,840 hrs/yr = 211,200 cars/yr.

Table 3-10. MATERIAL BALANCE FOR SPRAY APPLICATION OF SOLVENT-BASED PRIMER TO AUTOMOBILES

Item	Liters Per 211,200 cars[a]
Coating applied (24% solids by volume)	
• Coating (40% solids by volume as bought)	952,533
• Thinner	635,022
• Total coating applied	1,587,555
Material loss in the application (43% transfer efficiency)[b]	
• Solids	215,368
• Solvent discharge	
• Total material loss	1,278,512
Total coating on body (after flash-off)	309,043
Oven evaporation loss	
• Solvent discharge	143,398
Net dry solids on body	165,645

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[a] The annual production figure of 211,200 cars was derived as follows: (1) Production rate - 55 cars/hr; (2) Time - 2 shifts (8 hrs/shift) per day, 240 days/yr; or 55 cars/hr x 3,840 hrs/yr = 211,200 cars/yr.

[b] Transfer efficiency is the percentage of the total coating solids used that deposit on the surface of the object being coated.

Table 3-11. MATERIAL BALANCE FOR SPRAY APPLICATION OF SOLVENT-BASED ENAMEL TOPCOAT TO AUTOMOBILES

Item	Liters Per 211,200 cars
Coating applied (25% solids by volume)	
• Coating (31% solids by volume as bought)	1,881,053
• Thinner	451,451
• Total coating applied	2,332,504
Material loss in the application (43% transfer efficiency)	
• Solids	328,327
• Solvent discharge	1,545,718
• Total material loss	1,874,045
Total coating on body (after flash-off)	458,459
Oven evaporation loss	
• Solvent discharge	203,660
Net dry solids	254,799

amount of solvent in the paint. The process steps of solvent-based topcoat application were shown in Figure 3-3.

The loss of paint from overspray varies between 20 and 60 percent for solvent-based topcoats. Most automotive companies use waterwall-type spray booths. The used water from the spray booths goes to sludge tanks where solids are removed, and the water is recirculated. The sludge tanks are cleaned yearly.

Topcoat application is made in one to three steps to ensure sufficient coating thickness. An oven bake may follow each topcoat application or the paint may be applied wet on wet. The energy balance for solvent-based topcoat application is shown in Table 3-12.

Following the application of the topcoat, the painted body goes to the trim operation area where vehicle assembly is completed. The final step of the surface coating operation is generally the final repair process in which damaged paint is repaired in a spray booth and air-dried or baked in a low bake oven to protect the heat-sensitive plastic and rubber parts that were added in the trim operation area.

3.2.1.5 Equipment Characteristics

Automotive finishing process equipment from which VOC emissions emanate consists of spray booths, dip tanks, flash-off areas, and bake ovens. Other equipment includes specialized conveyors for moving the bodies and parts to be finished through the process.

Solvent-based primer and topcoat are applied by a combination of manual and automatic spraying techniques. Spray booth lengths vary from 100 to 200 feet. Because the bodies and parts are in the spray booth for a relatively long time, the majority of solvents are emitted in the spraying

Table 3-12. ENERGY BALANCE FOR APPLICATION OF SOLVENT-BASED ENAMEL TOPCOAT TO AUTOMOBILES

Operation Steps	10^6 Btu/Yr
Application[a]	39,016
Cure	195,947
Total	234,963

[a] This amount is highly dependent on climate since outside air must be heated to comfortable temperatures. The amount of heat required for this can be twice that required for curing.

area. High air flows through the booths dilute the vapors to such an extent that exiting concentrations of solvent vapor are very low.

To comply with the Occupational Safety and Health Administration regulations, a minimum air velocity within the booth is usually specified. As a result, organic vapors are in the vicinity of 50 to 150 ppm in the spray area.* However, even though the solvent concentration is low, the volume of exhaust is high and the total amount of solvent emitted can easily exceed the limit of 3000 pounds per day required by many state regulations. Temperature in the spray booths ranges from 15°C (60°F) to 35°C (95°F).

Spray booths of the waterwall type are most used in automobile production facilities. In a typical booth design, the overspray paint particles are removed by a curtain of water flowing down the side surfaces of the booth enclosure. Waterwall systems in several booths are connected to one or more large sludge tanks. The floating sludge is skimmed off the surface of the water. The water is then filtered and recirculated to the booths.

Bake ovens for the primer and topcoats usually have four or more heat zones. Oven temperatures range from 93°C (200°F) to 232°C (450°F), depending on the type of coating and the zone. A bake oven can safely operate at 25 percent of the lower explosive limit (LEL), and in many industries such concentrations are maintained. In the automotive industry, however, concentrations are much lower. One reason is that ovens are very long with large openings; hence, large amounts of air are pulled into them. Another reason is that ovens are designed to provide a bake environment that is not saturated with solvent, as air pressures in the oven tend to force available solvent vapors into the panel insulation.[9] The two major automobile and light-duty truck manufacturers report solvent concentrations at five percent of the LEL.[10,11] According to another source, solvent concentration in the oven may reach a maximum of about 10 percent of the LEL.[12]

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*Threshold limit for toluene or xylene: 100 parts/million (ppm). American Conference of Governmental Industrial Hygienists, 1973.

3.2.1.6 Emission Characteristics

The three types of solvent-based coatings used in the automotive industry are paints, enamels, and lacquers. Paints represent a small fraction of the total quantity of the coatings used in automotive surface coating operations. Paints are highly pigmented drying oils diluted with a low-solvency-power solvent known as thinner. Applied paints dry and cure in the oven by evaporation of the thinner and by oxidation during which the drying oil polymerizes to form a resinous film. Enamels are similar to paints in that they cure by polymerization. Many automotive coatings contain no drying oils but cure by chemical reaction when exposed to heat. Applied lacquers are dried by evaporation of the solvent to form the coating film.

The amount of solvent and thinners used in surface coating compositions varies, depending upon the plant in which they are used. The solvents used in enamels, lacquers, and varnishes are aromatic hydrocarbons, alcohols, ketones, ethers, and esters. The thinners used in paints, enamels, and varnishes are aliphatic hydrocarbons, mineral spirits, naphtha, and turpentine.

As mentioned previously, solvent emissions occur at the application and cure steps of the surface coating operation. Calculation of solvent emissions from representative plants resulted in the emission factors for the primer (solvent-based spray and EDP with guide coat) and topcoat operations given in Table 3-13. Assuming that the production rate of a finishing line is 880 cars per day (55 cars per hour, two 8-hour shifts per day), 10,329 kg of solvents (basis: density of 0.839 kg per liter) are discharged daily from the finishing operation.

Solid waste generated by the automotive finishing process was also determined based on data collected from the industry. Table 3-14 shows solid waste factors for the automobile surface coating operations.

The spray booths' water effluent contains contaminants from overspray of coatings. This effluent is discharged into sludge tanks, where solids are removed, and the water is recirculated. The sludge tanks are cleaned yearly when solvent-based coatings are used and four times per year for water-based coatings.

3.2.1.7 Factors Affecting Emissions

Several factors affect emissions discharged by the automotive industry. Naturally, the greater the quantity of solvent in the coating composition, the greater will be the air emissions. Lacquers having 12 to 18 percent volume solids are higher in solvents than enamels having 24 to 33 percent volume solids.

Production affects the amount of discharge of solvent emissions--the higher the production rate, the greater the emissions. This rate can also be influenced by the area of the parts being coated.

Emissions are also influenced by the thickness of the coating and technique used. There are no transfer problems when EDP is used; essentially all the paint solids are transferred to the part. There can be dripping associated with dragout, but this material is normally recovered

Table 3-13. AVERAGE EMISSIONS FOR AUTOMOBILE SURFACE COATING OPERATIONS

Coating	Application (liters/car)	Cure (liters/car)	Total
Primer- Solvent-based spray	5.03	0.68	5.71
Topcoat- Solvent-based spray	7.32	0.96	8.28
Total[a]	12.35	1.64	13.99
Primer- EDP	0.18	0.03	0.21
Guide coat- Solvent-based spray	1.24	0.17	1.41
Topcoat- Solvent-based spray	7.32	0.96	8.28
Total[b]	8.74	1.16	9.90

[a] Total for spray primer and topcoat applications.

[b] Total for EDP primer, guide coat, and topcoat applications.

Table 3-14. AVERAGE SOLID WASTE GENERATED FOR AUTOMOBILE SURFACE COATING OPERATIONS

Coating	Average Transfer Loss of Solids in Coatings (liters/car)
Primer- Solvent-based spray	1.02
Topcoat- Solvent-based spray	1.55
Total[a]	2.57
Primer- EDP	0.002
Guide coat- Solvent-based spray	0.250
Topcoat- Solvent-based spray	1.550
Total[b]	1.802

[a] Total for spray primer and topcoat applications.

[b] Total for EDP primer, guide coat, and topcoat applications.

in the rinse water and returned to the dip tank. Emissions of VOC from EDP are, therefore, very low.

In the case of spray coating, the transfer efficiency varies, depending on the type of spraying technique used. Transfer efficiency for nonelectrostatic spraying ranges from 30 to 50 percent; the range for electrostatic spraying is from 68 to 87 percent.[13]

State or intrastate regulations also influence emissions. Many States have statewide or district regulations for the control of hydrocarbon emissions from stationary sources.

3.2.2 The Basic Processes - Light-Duty Truck Industry

3.2.2.1 General

With little exception, the surface coating operations of a light-duty truck body are the same as for an automobile body. The production rate is usually slower than for automobiles, 35 to 38 units per hour versus 30 to 70 units per hour for automobiles. The process diagram in Figure 3-2 showed the consecutive steps of the light-duty truck surface coating operations. Unless otherwise noted, it may be assumed that statements regarding automobiles also hold true for light-duty trucks.

3.2.2.2 Primer Coating

Solvent emissions data for solvent-based primer were derived from information collected from light-duty truck manufacturers. The average solvent emissions of plants using solvent-based primer were calculated to be 5.31 liters per truck for the primer application. Assuming that a light-duty truck production line operates at a production rate of 38 light-duty trucks per hour and two (8-hour) shifts per day, 608 light-duty trucks are produced daily. This means that approximately 2,709 kg of solvent (basis:

density of 0.839 kg per liter) are discharged daily from the primer application process. A material balance showing the discharge of emissions at different steps in the solvent-based primer application process is presented in Table 3-15. Discharge of solvents to the atmosphere during primer application occurs as follows: 88 percent loss during application and 12 percent loss during oven drying of the coating. Energy requirements for the primer application in a light-duty truck production line are shown in Table 3-16.

3.2.2.3 Solvent-based Topcoat

Table 3-17 presents the base case material balance for solvent-based topcoat application. The energy balance for solvent-based topcoat operations is shown in Table 3-18. The process steps of the solvent-based topcoat operation were given in Figure 3-3.

Average percent solids content for solvent-based topcoat is 31 percent volume for light-duty trucks. The amount of overspray ranges from 35 to 60 percent for solvent-based topcoating.

3.2.2.4 Emission Characteristics

The types of solvent-based coating solvents and thinners used in the light-duty truck industry are essentially identical to those used for automobiles and described in paragraph 3.2.1.6, except that lacquers are seldom used for light-duty trucks.

As mentioned previously, solvent emissions occur at the application and cure steps of the surface coating operation. Calculation of solvent emissions from plants visited resulted in the emission factors for the primer and topcoat operations given in Table 3-19. Assuming that the production rate of a surface coating operations is 608 light-duty trucks

Table 3-15. MATERIAL BALANCE FOR SPRAY APPLICATION OF SOLVENT-BASED PRIMER TO LIGHT-DUTY TRUCKS

Item	Liters Per 145,920 Trucks[a]
Coating applied (30% solids by volume)	
• Coating (40% solids by volume as bought)	829,555
• Thinner	276,518
• Total coating applied	1,106,073
Material loss in the application step (43% transfer efficiency)	
• Solids	189,140
• Solvent discharge	681,340
• Total material loss	870,480
Total coating on body (after flash-off)	235,593
Oven evaporation loss	
• Solvent discharge	92,907
Net dry solids on body	142,686

[a] The annual production figure of 145,929 trucks was derived as follows: (1) Production rate - 38 trucks/hr; (2) Time - 2 shifts (8 hrs/shift) per day, 240 days/yr; or 38 trucks/hr x 3,840 hrs/yr = 145,920 trucks/yr.

Table 3-16. ENERGY BALANCE OF PRIME COAT APPLICATIONS FOR LIGHT-DUTY TRUCKS

Coating	Application[a] (10^6 Btu/hr)	Cure (10^6 Btu/hr)	Total
Solvent-based Spray Primer	12,403	38,818	52,221
EDP Primer	39,135	49,965	88,100

[a] This amount is highly dependent on climate since outside air must be heated to comfortable temperatures. The amount of heat required for this can be twice that required for curing.

Table 3-17. MATERIAL BALANCE FOR SPRAY APPLICATION OF SOLVENT-BASED ENAMEL TOPCOAT TO LIGHT-DUTY TRUCKS

Item	Liters Per 145,920 Trucks
Coating applied (28% solids by volume)	
• Coating (31% solids by volume)	1,603,807
• Thinner	171,835
• Total coating applied	1,775,642
Material loss in the application step (43% transfer efficiency)	
• Solids	281,701
• Solvent discharge	1,127,657
• Total material loss	1,409,368
Total coating on body (after flash-off)	366,284
Oven evaporation loss	
• Solvent discharge	150,805
Net dry solids on body	215,479

Table 3-18. ENERGY BALANCE FOR APPLICATION OF SOLVENT-BASED ENAMEL TOPCOAT TO LIGHT-DUTY TRUCKS

Operation Steps	10^6 Btu/Yr
Application	31,796
Cure	102,388
Total	134,184

Table 3-19. AVERAGE EMISSIONS FOR LIGHT-DUTY TRUCK SURFACE COATING OPERATIONS

Spray Primer and Tocoat Applications

Coating	Application (liters/truck)	Cure (liters/truck)	Total
Primer- Solvent-based spray	4.67	0.64	5.31
Topcoat- Solvent-based spray	7.73	1.03	8.76
Total[a]	12.40	1.67	14.07
Primer- EDP	0.18	0.03	0.21
Guide coat- Solvent-based spray	1.24	0.17	1.41
Topcoat- Solvent-based spray	7.73	1.03	8.76
Total[b]	9.15	1.23	10.38

[a] Total for spray primer and topcoat applications.

[b] Total for EDP primer, guide coat, and topcoat applications.

per day (38 vehicles per hour, two 8-hour shifts per day), 7,167 kg of solvent (basis: density of 0.839 kg per liter) will be discharged daily from the surface coating operation.

Solid waste generated by the light-duty truck surface coating operations was also determined based on data collected from the industry. Table 3-20 shows solid waste factors for the light-duty truck surface coating operations.

Table 3-20. AVERAGE SOLID WASTE GENERATED FOR LIGHT-DUTY TRUCK SURFACE COATING OPERATIONS

Coating	Average Transfer Loss of Solids in Coatings (liters/car)
Primer- Solvent-based spray	1.300
Topcoat- Solvent-based spray	1.930
Total[a]	3.230
Primer- EDP	0.003
Guide coat- Solvent-based spray	0.310
Topcoat Solvent-based spray	1.930
Total[b]	2.243

[a] Total for spray primer and topcoat applications.

[b] Total for EDP primer, guidecoat, and topcoat applications.

3.3 REFERENCES

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4. EMISSION CONTROL TECHNIQUES

4.1 GENERAL

This chapter and Chapter 6 both analyze the available emission control technology for the automobile and light-duty truck industry. Chapter 4 defines the emission reduction performance of specific control techniques; Chapter 6 evaluates complete emission control systems that combine finishing processes with one or more emission reduction techniques.

The control techniques discussed in this chapter minimize emissions of volatile organic compounds (VOC) to the ambient air. These VOC -- primarily ketones, alcohols, esters, saturated and unsaturated hydrocarbons, aromatics and ethers -- make up most of the solvents used for coatings, thinners, and cleaning materials in industrial finishing processes.

Several types of control techniques are presently used within the automobile and light-duty truck industry. These methods can be broadly categorized as either add-on control devices or substituting new coatings application systems. Add-ons reduce emissions by either recovering or destroying the solvents before they are discharged into the ambient air. Such techniques include thermal and catalytic incinerators and carbon adsorbers. New coatings become control methods when coatings containing relatively low levels of solvents are used in place of high solvent content coatings. Such methods include electrodeposition of water-based prime coatings and air or electrostatic spray of water-based and powder coatings. Because of the lower solvent content of the new coatings, these application methods are inherently less polluting than processes that use conventional solvent-based coatings.

The following discussion characterizes the control techniques and defines the emission reduction associated with each technique in the auto and light-duty truck industry.

4.2 THE ALTERNATIVE EMISSION CONTROL TECHNIQUES

4.2.1 Water-Based Coatings

Water-based coatings are the most common VOC control technique currently used in the automobile and light-duty truck industry. Most water-based coatings are applied as primers by electrodeposition; water-based spray topcoats and surfacers are used considerably less often than water-based primers.

The terminology for water-based coatings is confusing -- the names of the various coating types are often misused or used synonymously. The term water-based, as discussed here, refers to any coating that uses water primarily as the carrier and is meant to distinguish such coatings from solvent-based coatings.

There are three types of water-based coating materials: latex or emulsion coatings; partially solubilized dispersions; and water-soluble coatings. Table 4-1 lists the significant characteristics of these three water-based coatings. The indicated properties are not absolute, since individual coatings vary.

The following sections describe the two methods of applying water-based coatings used in automobile and light-duty truck surface coating lines -- electrodeposition and air spray.

TABLE 4-1. WATER-BASED COATINGS[1]

Properties	Latex or emulsion coatings	Partially solubilized dispersions	Water-soluble coatings
Resin particle size	0.1 micron	<0.1 micron	---
Molecular weight	1 million	50,000 - 200,000	20,000 - 50,000
Viscosity	Low, not dependent on molecular weight	Somewhat dependent on molecular weight	Very dependent on molecular weight
Viscosity control	Requires thickeners	Thickened by addition of cosolvent	Governed by molecular weight and solvent percent
Solids at application	High	Intermediate	Low
Gloss	Low	Low to medium-high	Low to highest
Chemical resistance	Excellent	Good to excellent	Fair to good
Exterior durbility	Excellent	Excellent	Very good
Impact resistance	Excellent	Excellent	Good to excellent
Stain resistance	Excellent	Good	Fair to good
Color retention on oven bake	Excellent	Excellent to good	Good to fair
Reducer	Water	Water	Water or water/solvent mix
Washup	Difficult	Moderately difficult	Easy

4.2.1.1 Electrodeposition

System Description

In electrodeposition (EDP) water-based dip systems, the vehicle to be coated is immersed in a water-based coating, and an electric potential difference is induced between the vehicle and the coating bath. Current flow through the bath causes the coating particles to be attracted to and deposited on the metal surface. By correctly setting the electrical potential and the time in the bath, the coating thickness can be controlled within 5 x 10^{-3} millimeters (0.2 mil). Corrosion protection is excellent because coverage is more complete than can be obtained by spray priming alone. Figure 4-1 shows a typical EDP process with coating and water reuse. Such systems have been described in detail in the literature.[2,3,4,5]

The paint in the bath consists of 5 to 12 volume percent solids, 80 to 90 volume percent water, and about 5 volume percent organic cosolvent.[4,6,7] Organic solvents used in water-based coatings are high molecular weight organic compounds; these compounds are added to help fuse the coating particles into a continuous film. The coating solids displace solvent as they are deposited, and the solvent is squeezed out. As the vehicle component emerges from the bath, its coating is about 90 to 95 volume percent solids, 5 to 9 volume percent water, and less than 1 volume percent organic cosolvent. Excess coating is washed from the vehicle with a spraywash. The solids are concentrated by ultrafiltration and returned to the bath while the water is recycled to the spraywash.

Only water-based coatings can be applied by electrodeposition (EDP). Currently, EDP (also called electrocoating) is used in more than half of the existing assembly plants for applying automotive primers to bodies and parts. Traditionally, in applying EDP coatings the tank or

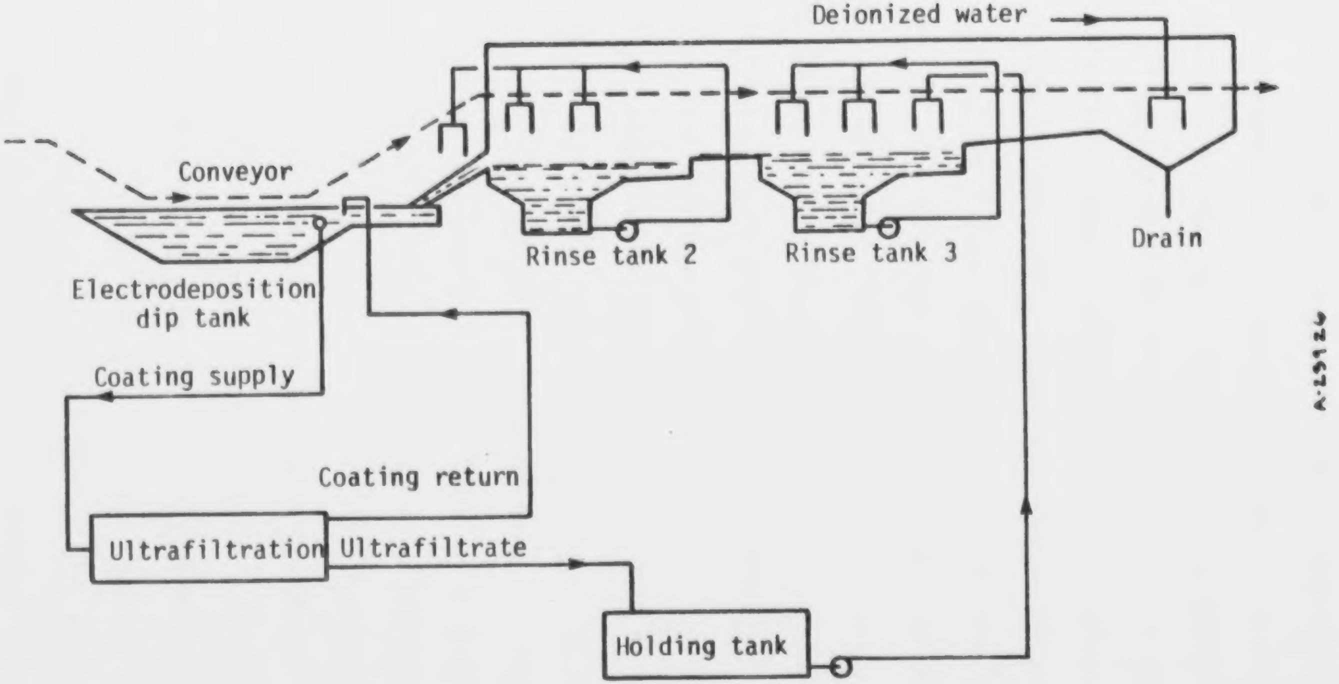

Deionized water
Conveyor
Rinse tank 2
Rinse tank 3
Drain
Electrodeposition dip tank
Coating supply
Coating return
Ultrafiltration
Ultrafiltrate
Holding tank
A-25926

Figure 4-1. Typical electrodeposition system.

grids on the periphery are negatively charged while the part is grounded.[8] This is called anodic EDP.

Cathodic EDP, in which the part is negatively charged, is a new technology which is expanding rapidly in the automotive industry. Increased corrosion resistance and lower cure temperatures (generating less odorous organic emissions) are two main reasons for this change from anodic to cathodic systems. Cathodic systems are also capable of applying better coverage on deep recesses of parts. Since cathodic EDP has these advantages, and industry is presently converting to cathodic, it will be used as the base EDP system in this document.

In a typical EDP operation, bodies or parts are loaded on a conveyor that first carries them through a pretreatment section for cleaning. The treated and washed bodies or parts are automatically lowered into the EDP tank containing the water-based coating. To avoid marking the coating, direct current electrical power is not applied until the part is totally submerged. Current flow through the bath causes the coating particles to be attracted to the metal surface, where they deposit as a uniform film. The polymer film that builds up tends to insulate the part and prevent further deposition. Dwell time in the tank is typically 1-1/2 to 2 minutes.[4,6,9,10]

The current is then shut off. The parts are raised out of the bath, allowed to drain, rinsed to remove dragout, and then baked. Solids from the dragout are collected in the rinse water and are usually returned to the EDP tank. This recovery can result in coating savings of 17 to 30 percent.[11,12] Excess water is removed from the coating bath using an ultrafilter.

After electrodeposition, the coatings are baked; the solvent and water evaporate to leave a cured film that closely resembles a solvent-based finish.[13] Some EDP coatings contain amines that are also volatilized during curing. Since these amines can produce malodors or visible emissions some oven exhaust gases are incinerated. Such emissions and malodors are minimal for cathodic EDP, which uses a lower cure temperature than anodic systems.

The solubilized resins used in automobile and light-duty truck primers are generally based on malenized oils or malenized polyester. These resins are combined with pigments, such as carbon black and iron oxide, and are dissolved in a water-solvent mixture which contains about 5 percent organic cosolvent. The solvents used are typically higher molecular weight organic compounds, such as ethylene glycol monobutyl ether (butyl cellosolve$^{\text{TM}}$).[8]

Parts coated by EDP are normally baked from 15 to 30 minutes at 160° to 190°C (300° to 400°F), with the higher temperatures being used for automobile and truck primers.[2,4,14,15,16]

The conveyors, pretreatment section, and bake oven used for EDP are conventional items. The critical components of the EDP system include the following:[14,17]

- Dip tank -- The dip tank is a large rectangular container generally with a capacity of 120,000 to 320,000 liters (32,000 to 85,000 gallons), depending on part size.[18] Larger tanks are used for priming bodies, while smaller units are used for coating parts, such as fenders and hoods. The tanks are coated internally with a dielectric material, such as epoxy, and are electrically grounded for safety.[4,9] Shielded anodes are submerged and usually run along both sides of the tank

- Power supply -- Direct current electrical power is supplied by a rectifier which has a capacity of approximately 250 to 500 volts and 300 to 2500 amperes, depending on the number of square feet per minute to be finished
- Heat exchangers -- Coating drawn from the dip tank is passed through a heat exchanger to dissipate heat that is developed during the coating operation. The temperature is normally maintained at 20^0 to $24^0C \pm 1^0C$ (68^0 to $75^0F \pm 2^0F$).[4,7,9]
- Filters -- An in-line filter is also placed in the recirculating system to remove dirt and polymer agglomerates from the coating
- Pumps -- Recirculating pumps are used to keep the coating solution stirred
- Ultrafiltration unit -- Excess water is removed from the coating in this unit. The concentrate, with the coating, is returned to the dip tank. The excess water, called permeate, is used as rinse water.
- Coating mixing tank -- Coating mixing tanks are used to premix and store coating solids for adding to the dip tank as needed
- Control panel -- The electrodeposition process is generally controlled from a central control console. This panel contains all start-stop switches plus instruments for monitoring voltage, amperage, coating temperature, and pH.

Factors Affecting Performance

Proper pretreatment can be critical to coating performance, particularly if the substrate has grease or oil on the surface. Solvent-based coatings will usually dislodge an occasional oil spot, but water-based will not.[19] Cleaners developed for solvent-based coating systems are generally adequate for EDP.

Similarly, for satisfactory appearance of the final finish, the parts should be rinsed thoroughly after the EDP coating has been applied; the final rinse should be deionized water.

Coating in the dip tank is affected by voltage, current density, temperature, dwell time, pH, and solids content.[20] For successful operation of an EDP system, these parameters must be monitored on a regular basis. By increasing the voltage or the temperature in the bath, the film thickness can be slightly increased. However, excessively high voltage will cause holes in the films because of gassing. Too high a temperature is also undesirable; some coatings will flocculate at temperatures approaching 90°C. Refrigeration of the bath is necessary to maintain temperatures below this point. At high pH, a reduction in the deposition occurs; if the pH drops below the isoelectric point (acidity level where dispersing forces equals cohering forces), the total coating in the bath can coagulate. If the solids content in the coating is too high, the voltage pulls the solids strongly enough to press the moisture from the deposited film; if the bath is too dilute, then the film will be thin. Film buildup is usually about 0.018 millimeters (0.7 mil).

Solvent emissions are related to both coating composition and production rate. The greater the quantity of solvent in the water-based coating, the greater the air emissions. Production rate has an influence on emissions: the higher the rate, the greater the emissions. This rate depends on the area of the parts, their spacing on the conveyor, and the conveyor speed.

Normally, there are no solids transfer loss problems with electrodeposition; nearly all the coating solids are transferred to the part. Dripping can be associated with dragout, but this material is recovered in the rinse water and returned to the dip tank.

When an emission reduction is achieved by replacing solvent based primer by a low solvent substitute, the percent reduction is related to the emission level of the original solvent which depends on the percent solvent in the coating and on the transfer efficiency. The reduction is also related to the EDP system emissions which are equal to the organic solvent added to the tank; normally just the organic solvent in the coating applied, since solids transfer is 99+ percent complete.

Application

EDP is not used alone for most automobile and light-duty truck primers. Most employ a primer surfacer, also called surfacer or guidecoat, to build film thickness and permit sanding between the primer and topcoat. These primer surfacers are applied by spraying and can be either solvent or water-based. Because of the solvent content, they can have a significant effect on the overall solvent emissions for primer operations (see Chapter 6 -- Emission Control Systems).

4.2.1.2 Water-Based Spray

Since applying water-based coating by EDP is limited to one-coat priming, auto manufacturers have chosen spray coating for applying water-based surfacers and topcoats.[21,22,23] Such surfacer and topcoat systems are used in production at three General Motors plants;[21,22] a similar, but experimental, line in Canada is operated by the Ford Motor Company.[23] A General Motors automobile plant recently started up in Oklahoma City uses water-based guidecoat and topcoat and a light-duty truck plant being planned for Shreveport, Louisiana may use water-based guidecoat and topcoat.

The topcoat materials used are thermosetting acrylics with 23 to 25 volume percent solids and water/solvent ratios of 80/20 to 88/12 in the liquid portion of the coating.[21,22,23,24,25] These coatings contain a solvent to solids ratio in the range of 0.30 to 0.67 by volume.

As with any coating airborne emissions, volatile organics from water-based guidecoat and topcoat operations depend on the percent solids and solvent in the coating and the thickness of the coating that is applied.

One critical factor in any spray operation is transfer efficiency or that percentage of the coating applied that actually deposits on the part. This factor can have serious effects on emissions, cost, and secondary pollutants.

By surveying the industry, an investigator found that spray efficiencies depended on the manner of coating application and charge on the solids.[26] Transfer efficiencies of 30 to 60 were reported for common air spray systems which averaged 43 percent for organic and water-based coating. Continuous monitoring of the process line spray control should ensure transfer efficiencies will remain up to 40 percent even when spraying thicker coats.

4.2.1.3 Combination of EDP and Water-Based Topcoat

The advanced technology of utilizing water-based spray coating for surfacing and topcoat finishes, subsequent to the electrodeposition primer, has become operational for three automobile assembly plants. Although costs and energy requirements are higher, these systems have been successful in producing a satisfactory product that has less than a quarter of the VOC emissions typical of solvent coatings.[27]

The general finishing processes for the three General Motors plants using water-based surfacer and topcoats are similar.[21,22] The finishing process at the General Motors South Gate, California plant has been described as follows:[27]

1. A conventional cleaning and phosphating with no dry-off
2. An electrodeposition primer application followed by baking
3. Applying sealers
4. Coating with an epoxy ester-based water-based spray primer surfacer (guide-coat) using automatic and manual air spray
5. Flash-off for 5 to 8 minutes in a 77° to 93°C (170° to 200°F) tunnel
6. A partial bake
7. Applying interior coating plus additional sealant. The coating used here is a water-based acrylic enamel.
8. Final baking of the primer
9. Wet-sanding and masking of the interior
10. Applying a water-based acrylic enamel topcoat in two separate booths with a flash-off and set-up bake after each application
11. Coating the trunk with a water-based emulsion coating
12. Touch-up and accent color application in a third booth
13. A final bake at 163°C (325°F) for 30 minutes

In addition to automobile topcoats, water-based coatings are also being used to finish components, such as wheels and engines.[28,29,30]

4.2.2 Powder Coating

Powder coating, although considered here as a new coating method, has been used since the 1950's.[31] Fluidized-bed coating began in the early 1950's, and electrostatic spray of powder was introduced in the early 1960's. Powder coating involves applying 100 percent solid materials in dry powder form; no solvents are used, although traces of organics can be driven off from the resins during curing. Such a system emits small quantities of VOC; however, its use is limited to small specific industry lines that can accept the lower flowout quality of coating finish.

Powder coating materials are generally available as both thermoplastic and thermosets, but the thermosets are the only materials used to provide thin, high-performance finishes as used for automobiles and light-duty trucks. Powder coating is being used throughout the industrial finishing industry for such diverse painting applications as metal furniture, wire goods (baskets, racks, and shelves), piping, tubing, fencing, posts, garden tractors, lawn equipment, and bicycles.[32,33,34]

In the U.S. automotive industry, powder coating has been used on two pilot lines for applying topcoats and has also been applied to under-the- hood parts, such as oil filters and air cleaners, as well as bumpers, trailer hitches, and emergency brake cable guides.[35-41]

In Japan, Honda is topcoating cars with powder at a continuous production rate and Nissan Motor Company began applying powder topcoats to trucks sometime during 1977.[42] Nissan is constructing a new plant at Kanda, North Kyushu, where powder topcoats will be applied to light-duty trucks. Trucks will be finished in one of eight colors; all applied in a single spray booth.[43]

The most significant use of powder for automobile finishing in the U.S. is a pilot line being used for applying topcoats by the Ford Motor Company at Metuchen, New Jersey. This line has been successfully finishing Pintos in solid colors since 1973.[36] Cars from this line can be obtained in one of eight colors. The powder coating operation has been placed adjacent to the main assembly line. Before powder finish, cars are pretreated and primed in an identical manner to cars receiving conventional finishes. Cars to be powder coated are moved from the main assembly line and are painted by electrostatic spray in one of two booths. The bulk of the coating is applied with automatic powder guns. Inaccessible areas are hand sprayed. Overspray is approximately 35 percent,[36] most of which is recovered. For good flowout, a 6.3 to 7.6 x 10^{-2} millimeters (2.5 to 3.0 mil) coating is applied, which equals approximately 2.9 kilograms (6.5 pounds) of topcoating per car.[36] To fuse and cure the coating, the cars are baked at 177°C (350°F) for 30 minutes. Following finishing and baking, the cars are moved back into the main assembly line.

However, Ford has not successfully demonstrated applying powder metallic coatings. In applying solvent-based coating, the viscosity is low enough for the metallic flakes to turn and orient parallel to the surface as the coating dries. With powder, the molten polymer is viscous; the flake keeps a random orientation, making the appearance less aesthetically pleasing. This is of great importance, since metallic coated vehicles account for over 50 percent of sales. A demonstrated control option must be applicable to a major segment of the industry. The unavailability of metallic powders becomes a critical factor in using powders because frequent color changes, including metallics, are required in normal assembly operation.

On a typical automobile or light-duty truck assembly line, the color of the topcoat is determined by individual orders, which may come completely at random. This requires a color change after each vehicle. The time allowed for the change is dictated by the line speed, which permits approximately 13 seconds between vehicles. Color changes require removal of essentially all powder from the booth, lines, and guns as color contamination will give the finished coat a salt-and-pepper look from dissimilar color particles.[44] Ford has been able to modify their equipment to meet these requirements for one basic line.

Since metallic powder coatings are not currently available, powder coatings are not considered a demonstrated control option for the purpose of this study.

4.2.3 New Coating Development

New coatings containing higher solids fraction are attractive because they can potentially be used to apply the same weight of paint solids as typical coatings but have reduced volatile organic emissions. These coatings are either categorized as radiation curable systems, higher solids nonaqueous dispersion coatings, high-solids coatings, or powder coatings. Powder coating, the most fully developed but use-limited system has already been discussed (Section 4.2.2).

Radiation-Cured Coating

Radiation-cured coating involves photocuring mixtures of low molecular weight polymers or oligomers dissolved in low molecular weight acrylic monomers. These formulations contain no solvent carriers and can be cured using either electron beam or ultra-violet light sources.[45,46,47] Although attractive because of low VOC generation, these coatings have gained little interest in the auto industry. Presumably, this lack of interest is because of the health hazard associated with spray application of these relatively toxic monomer mixtures and the difficulties involved in obtaining adequate cure of paint when it is applied to irregularly shaped substrates.

Medium-solid Nonaqueous Dispersion

During the early 1970's, medium-solid nonaqueous dispersion (NAD) coatings began to generate interest as spray topcoats for domestic and foreign automobiles. As a result, several companies are now using NAD coatings on automobile and truck assembly lines for applying both lacquer and enamel topcoats.[48,49]

NAD enamels used in the industry have essentially the same solvent contents as their solution enamel counterparts. Although higher solids contents are technically feasible, these have not been realized because of application and appearance problems. Therefore, the present NAD enamels are no less polluting than solution enamels.

Most of the impetus behind the switch to NAD coatings was because dispersion coating builds sufficient film rapidly without the sagging and solvent popping usually associated with solution enamels and lacquers. Using NAD lacquer also allowed spray application at almost double the usual solids for solution lacquers, thereby cutting the required number of coats by 40 to 50 percent. These improved application performances made it possible to shorten coating line time by 50 to 60 percent without capital investment in equipment or facilities.[50]

Presently in the industry, topcoats are being applied either from nonaqueous dispersion and solution lacquers or from nonaqueous dispersion enamels. A small percentage of automobiles are still being finished with solution enamel paints.

Most of the automobiles produced at General Motors are finished with lacquers; these represent about half the domestic production. These lacquers range from approximately 12 to 18 volume percent solids applied, depending on whether the lacquer is a nonaqueous dispersion or a solution.

Most of the vehicles manufactured by Ford, Chrysler, and American Motors are being topcoated with NAD enamels. General Motors uses these coatings for their trucks. These enamels vary in their degree of dispersion; in fact, some come very close to being solutions. Solid color NAD enamels, which are relatively low in dispersion, are supplied at a solids content generally in the range of 39 to 42 volume percent. Metallic NAD enamels tend to be higher in dispersion than solid colors and are normally supplied at 33 to 37 volume percent solids:[48,49] these enamels are then diluted with solvent for application.

High-solids coatings

High-solids coatings are relatively new materials currently being developed and investigated in the automotive, can, coil, and appliance industries. The attraction of high-solids coatings (technically a medium high solids content) seems to be their low solvent content, the promise of application with conventional finishing equipment, and the promise of energy savings through the use of more efficient application. Although the traditional definition of high solids as specified in "Rule 66" indicates no less than 80 volume percent solids,[51] most people in industry consider everything from 60 to 100 percent as high solids. High-solids coatings will very likely not contain radically new resin binders; most will be modifications of their low-solids counterparts.

These coatings can be categorized as either two-component/ambient-curing or single-component/heat-converted materials. The coatings of the most immediate interest are the two-component/ambient-cured materials; they offer a reduced solvent content and tremendous energy savings since they require little, if any, baking.

Heat-converted, high-solids coatings, on the other hand, are baked at temperatures similar to their low-solids counterparts -- nominally 150° to 175°C (300° to 350°F). Resin systems being investigated for two component materials include epoxy-amine, acrylic-urethane, and urethane.[52,53,54,55]

The most significant problem with high-solids coatings is the high working viscosity of the solution (due to solids at 60 to 80 volume percent).[54] The viscosity can be partially controlled by reducing the molecular weight of the base polymer or by using reactive diluents, but these techniques can result in a greatly altered product with inferior properties. Heating the coating during the application is a more effective means of reducing viscosity.[54] Heated high solids can be applied as airless, air, or electrostatically sprayed finishes from heated equipment.[55] They can also be roll coated.

In general, high-solids coatings hold a great deal of promise. However, they are an emerging technology and are considered still in their infancy.[56] Of the approximately 1514 million liters (400 million gallons) of industrial finishes consumed in 1975, less than 1 percent were high solids.[57] Most of these high solids coatings were used in coil and can coating. None were used in the automotive industry. Recent developments on 50 to 60 percent solids coatings indicate that they are feasible for automobile finishes and are expected to be widely used by 1982.

The exhaust from the spray booths, particularly during periods of cool ambient temperatures, can become saturated with moisture[62]. One solution to this problem would be to preheat the moisture-laden air to lower the relative humidity below 80 percent; a 4° to 5°C (7° to 9°F) temperature rise would be sufficient.[68]

Before adsorption, particulates from oversprayed coating should be removed from the air streams, since this material coats the carbon and plugs the interstices between carbon particles. Such plugging reduces adsorption efficiency and increases pressure drop through the bed. These particulates can be removed by using either a fabric filter[67] or the combination of a centrifugal wet separator plus prefilter and bag filter.[66]

Another variable that should be considered in designing an adsorber for this application is the potential variability of the solvent systems between different grades or types of coatings. Although all automotive spray coatings contain the same families of solvents (i.e., glycol ethers, esters, C_8 and C_9 aliphatics), the various coatings used can differ widely in specific compounds and relative proportions. Therefore, solvent systems differ in their adsorptive characteristics and in their ability to be removed by the adsorber. On lines where different coatings are periodically used, adsorbers will probably have to be overdesigned in adsorptive capacity to be reliable.

Applicability to Bake Ovens

Ovens are the second major source of solvent emissions. Adsorbers for ovens will have to be designed to handle a different solvent mix than is found in spray booths and flash-off areas. The solvent emitted in the spray booth and flash-off area comprises a large percentage of low boiling point organic compounds, such as acetone, butanol, and toluene. Solvent remaining in the film as it enters the oven contains the less-volatile solvents. High-boiling point solvents may not consistently be completely stripped during activated carbon regeneration; thus, more frequent replacement of the carbon would be likely. Hot gas or superheated steam regeneration would probably be required to improve their removal.[69]

In the oven, high temperatures and flame contact can cause polymerization of the volatiles into high molecular weight resinous materials that can deposit on and foul the carbon bed. Various high molecular weight volatiles in the coatings, such as oligomers, curing agents, or plasticizers, can cause a similar problem. Filtration and/or condensation of the oven exhaust air would be necessary before adsorption to remove these materials. Further, to get satisfactory performance, the oven exhaust would have to be cooled to no greater than $38^{o}C$. Without cooling, many of the more volatile organics will not adsorb but will pass through the adsorber.[70,71]

Carbon adsorption cannot be considered as a viable control option at this time because this auxiliary equipment has not been demonstrated as economically feasible.

4.2.5 Incineration

Incineration is the most universally applicable technique for reducing the emission of volatile organics from industrial processes. While incineration of many industrial wastes may have adverse byproducts of SO_x and NO_x emissions, these are not a concern for finishing coatings which are principally hydrocarbons.

Industrial incinerators or afterburners are either noncatalytic (commonly called thermal or direct fired) or catalytic.[72] There are sufficient differences between these two control methods to warrant a separate discussion for each.

4.2.5.1 Thermal Incinerators

System Description

Direct-fired units operate by heating the solvent-laden air to near its combustion temperature and then bringing it in direct contact with a flame. In general, a temperature of 760°C (1400°F) is sufficient for nearly complete combustion. A typical unit is shown schematically in Figure 4-2.

To prevent a fire hazard, industrial finishing ovens are seldom operated with a concentration of solvent vapor in the air greater than 25 percent of the lower explosive limit (LEL), about 6000 ppm. Ovens in the automobile and light-duty truck industry achieve concentrations of only 5 to 10 percent LEL. These low concentrations are the result of the high air flows that prevent oven gas escaping from oven openings and high-boiling point organics condensing on the inner surfaces of the oven.[73]

In spray booths, the concentrations are maintained at even lower levels to protect the health and safety of the workers. Although most spray booths currently operate at no more than 2 percent of LEL (see Section 4.2.6), some plant innovations have helped maintain workers' safety and also generated more concentrated air streams.

Because of the low VOC concentrations from current ovens and spray booths, auxiliary heating is required to burn the vapors. Natural gas combustion usually provides the energy for direct flame contacted, thermal incinerators. Propane and fuel oil are also used.[74,75] For most solvents the fuel value is equivalent to 18,630 joule per cubic meter

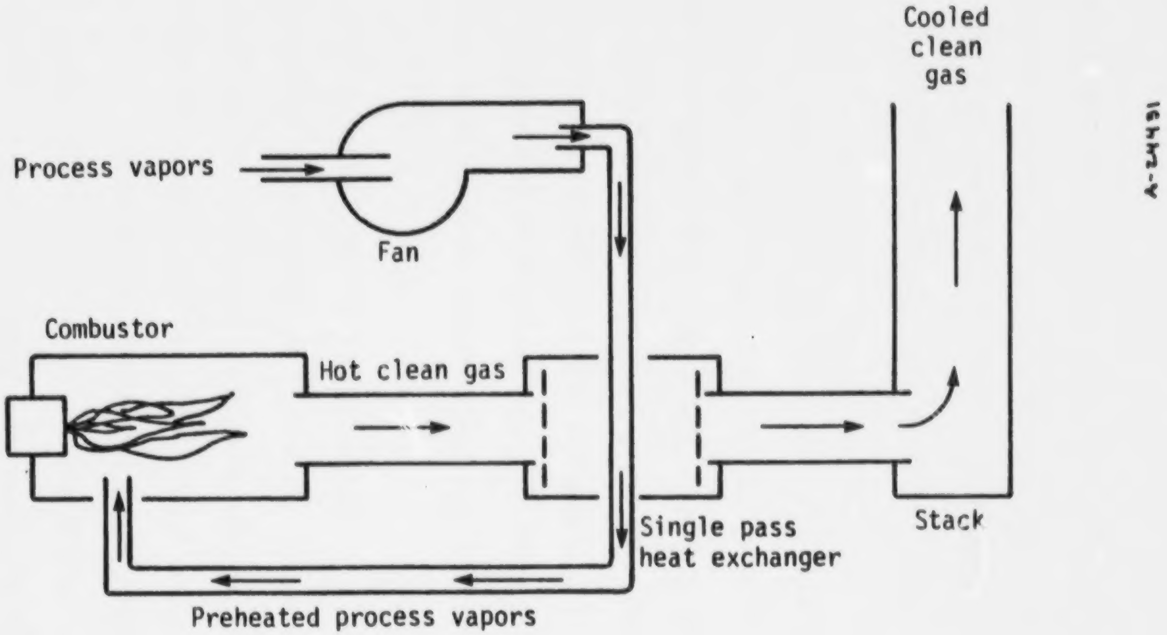

Cooled
clean
gas
Process vapors
Fan
Combustor
Hot clean gas
Single pass
heat exchanger
Stack
Preheated process vapors
A-24491

Figure 4-2. Forced-draft incineration system eliminating solvent vapors from surface coating process.[76]

(0.5 Btu/scf), which translates into a temperature rise of approximately 15.3°C (27.5°F) for every percentage point of LEL that is incinerated.[77] For an air stream with a solvent content of 10 percent of LEL, the contribution from the heat of combustion of the solvent would be approximately 188,370 joule per cubic meter (5 Btu/scf);[77] this equals a temperature rise of 138°C (248°F) at 90 percent combustion efficiency. For a spray booth exhaust at 2 percent LEL, the solvent would contribute only 28°C (50°F) to the temperature rise needed to bring the gases up to the 816°C (1500°F) required for complete combustion.

To reduce fuel costs of thermal incineration, primary heat recovery is often used to preheat the incoming process vapors as illustrated in Figure 4-2.[78] Recuperative or fixed surface heat exchangers, either tube or plate type, are capable of recovering 50 to 70 percent of the heat from the original fuel input.[78,79]

The regenerative heat exchanger, widely used in vapor incineration equipment, contains either refractory or rotary tube or plate surfaces that are capable of 75 to 90 percent heat recoveries.[78,80,81,82] In some cases, secondary recovery is also used to convert additional exhaust heat into process steam or to warm makeup air for the plant.[78]

Factors Affecting Performance

Temperature and residence time are the main operating parameters that affect the emission reduction potential of thermal incinerators for automobile and light-duty truck coating operations. For complete combustion of the hydrocarbons in the air stream, sufficient temperature and residence time must exist in the incinerator. Figure 4-3 shows the combined effect of these two parameters on pollutant destruction. From the table, it can be seen that for typical residence times of 0.3 to

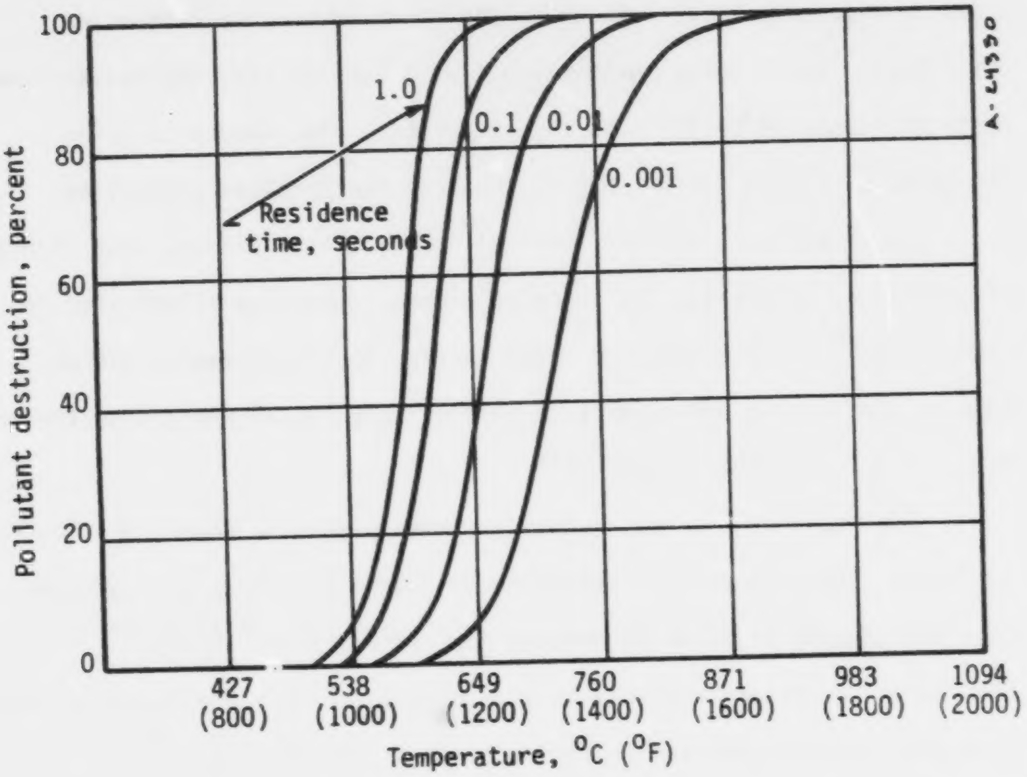


Figure 4-3. Coupled effects of temperature and time on rate of pollutant oxidation.[77]

1 second, and temperatures of 700^{o}C (1290^{o}F) are necessary for complete combustion to occur. Solvent type also can influence incinerator performance. While 677^{o}C (1250^{o}F) is adequate to combust most solvent vapors, certain organics from coating solids require temperatures of 760^{o} to 816^{o}C (1400^{o} to 1500^{o}F) for nearly complete oxidation.[72]

In the automobile and light-duty truck industry, the emissions from spray booths and baking ovens are the two areas of highest potential for using incinerators. Their use on bake oven exhaust can be implemented with minimal difficulty. Such add-on control devices are in place on ovens in several assembly plants, particularly in California. Typical emission reduction with such units is over 90 percent.[64,83,84] Since the air exiting the ovens is generally at a temperature of 120^{o} to 150^{o}C (250^{o} to 300^{o}F), air preheating requirements are small.

As stated earlier, bake ovens contribute only about 10 percent of the solvent emissions from coating operations and therefore applying incinerators to bake ovens would control only a small fraction of the total VOC emissions. The remaining 90 percent of the volatiles are emitted in the spray booth. Although incinerating of the air from spray booths is possible, there has been no application in the automobile and light-duty truck industry. Because of the large air flow in the spray booths (as much as 94 to 188 cubic meters per second or 200,000 to 400,000 cfm), the resulting low solvent content of the air (2 percent LEL or less) and the low temperature of the exhaust gas, large quantities of natural gas or equivalent fuel would be required to heat the vapor-laden air to the 700^{o} to 760^{o}C (1300^{o} to 1400^{o}F) necessary to effect nearly complete combustion.

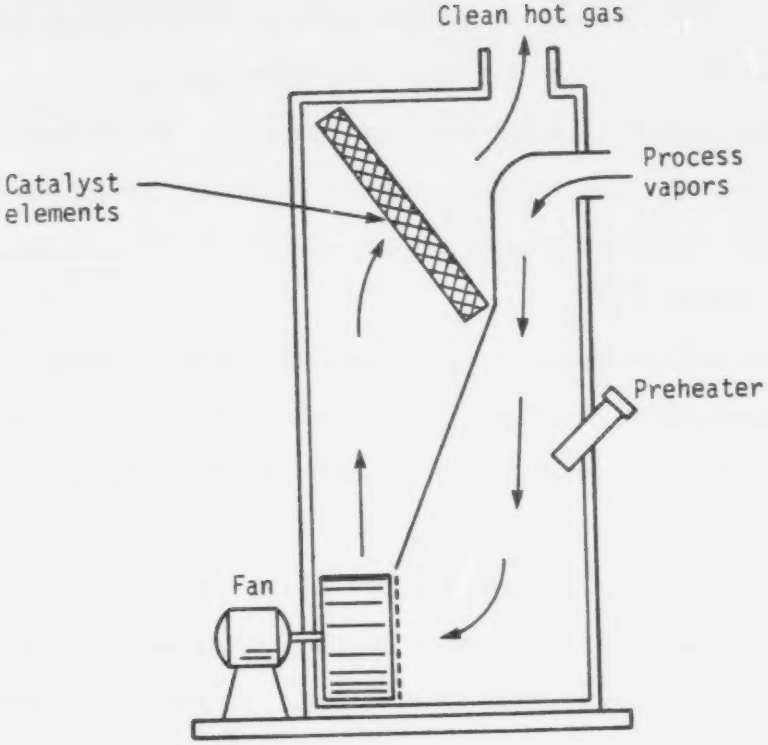
Attention has been given to a potential legal conflict with incinerating spray booth exhaust air. NFPA No. 33-1973, Section 4.2, (also OSHA regulation Part 1910.107 FR) specifically prohibits open flames in any spraying area; Section 1.2 defines a spraying area as: "(b) The interior of ducts exhausting from spray processes." However, Section 4.2.1 states: "Equipment to process air exhausted from spray operation for removal of contaminants shall be approved by the authority having jurisdiction." Section 4.2.1 would allow using incineration for spray booth exhaust air so long as the local authority approved; thus the OSHA regulation is not considered a limitation on this technology.

4.2.5.2 Catalytic Incineration

This add-on control method uses a metal catalyst to promote or speed combustion of volatile organics. Oxidation takes place at the catalyst surface to convert organics into carbon dioxide and water without actually flaming, as it permits lower operating temperatures than needed for direct-fired units.[72]

A schematic of a typical catalytic afterburner is shown in Figure 4-4. The catalysts, usually noble metals such as platinum and palladium, are supported in the hot gas stream so that a large surface area is presented to the waste organics. A variety of designs is available for the catalyst, but most units use a noble metal electrodeposited on a larger surface area support structure, such as ceramic rods or honeycombed alumina pellets.[72,85] Catalytic incinerators can potentially reduce volatile organic emissions and are currently used for minor emissions in the automotive industry.[86]

As with thermal incinerators, the performance of the catalytic unit depends on the temperature of the gas passing across the catalyst and on



Clean hot gas
Catalyst elements
Process vapors
Preheater
Fan
A-34221

Figure 4-4. Schematic diagram of catalytic afterburner using torch-type preheat burner with flow of preheated process vapors through a fan to promote mixing.[77]

the residence time. Temperatures are normally in the range of 260° to 315°C (500° to 600°F) for the incoming air stream and 400° to 540°C (750° to 1000°F) for the exhaust. The exit temperature from the catalyst depends on the inlet temperature, the concentration of organics, and the percent combustion.

Burning efficiency varies with the type of organic being oxidized as well as the detention time and temperature.[85] These effects of temperature and organic type are shown in Figure 4-5. While high temperatures are desirable for good emission reduction, temperatures in excess of 593°C (1100°F) can cause serious erosion of the catalyst through vaporization.[72,85]

As with thermal incinerators, primary and secondary heat recovery can be used to minimize auxiliary heating requirements for the inlet air stream and to reduce the overall energy needs for the plant (see Section 4.2.5.1).

Although catalysts are not consumed during chemical reaction, they tend to deteriorate, causing a gradual loss of effectiveness in oxidizing the organics. This deterioration is caused by: poisoning with chemicals, such as phosphorous and arsenic, which react with the catalyst; by coating the catalyst with particulates or condensates; and by high operating temperatures, which tend to vaporize the noble metal. In most cases, catalysts are guaranteed for 1 year by the equipment supplier,[87] but with proper filtration cleaning and attention to operating temperatures the catalyst should have a useful life to 2 to 3 years.[72,87,83]

While catalytic incinerators can probably be adapted to baking ovens with relatively little difficulty, using these add-ons for

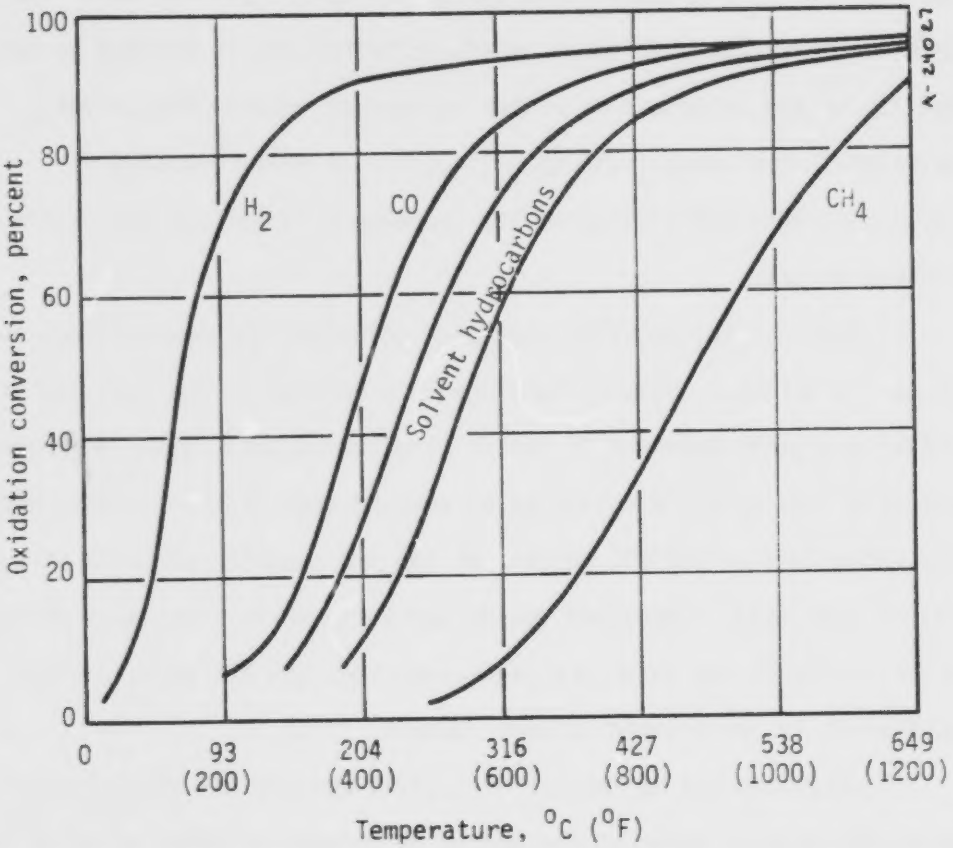


Figure 4-5. Effect of temperature on oxidative conversion of organic vapors in a catalytic incinerator.[77]

controlling spray booth and flash-off area emissions will require solving the same design problems discussed for thermal incinerators.

4.3 EMISSION REDUCTION PERFORMANCE OF CONTROL TECHNIQUES

4.3.1 Method of Determining Emission Reduction

Emissions can be controlled either through substituting new coatings for solvent-based coatings or add-on control devices. The emission reduction attainable by add-on technology is related to the ability of the technique to either capture or destroy the solvent emissions. Measurement and quantification of this reduction is straightforward and similar to the approach used for any end-of-line control device.

However, the emission reduction potential for new coatings is not as easily defined. Solvent emissions are related to the quantity of volatile organic material in the coating before application and cure. The potential reduction in emissions by coating substitution is determined by the difference in the VOC content of the two coatings per unit of coating solids deposited. Deposited solids are the same in both cases while organic solvent and water are vaporized, thus the VOC emissions are equivalent to the organic solvent content.

Emissions due to the use of a given coating can be expressed quantitatively in terms of the amount of solvent or other volatile organic compound emitted per unit of dry coating solids applied. This approach relates emissions directly to each unit of coating material actually applied to an automobile or truck independent of size of the vehicle, production rate, or dilution air flowrate. Emissions due to a specific coating can be derived from a chemical analysis of the paint and can be expressed as the ratio of VOC (measured as carbon) per unit volume solids (see Appendix C). Alternatively, it can be derived from the total mass of the organic solvent in the coating, again per unit solids content. This measure would be expressed as kilograms VOC per liter solids. The two derived values will not be the same but will differ by a factor of the solvents' relative carbon content. Emissions of VOC reported in the literature are based on solvent quantity. Appendix D discusses the relative uncertainties of a standard based on this measure versus one based on carbon content.

To determine the quantity of applied solids for the above emission determination, it is necessary to consider the transfer efficiency of the application system or the percentage of paint used that actually deposits on the surface. For spray application, transfer efficiencies of 30 to 50 percent are normal when using air spray; electrostatic spray will improve depositions to 60 to 90 percent (see Section 4.2.1.2).

Emission reduction potential discussed below for various coating systems is given in terms of kilogram VOC/liter applied solids. The following techniques are discussed: electrodeposition of water-based coatings; water-based spray coating; powder coating; higher solids coatings; carbon adsorption; and incineration. Powder coating and carbon adsorption are included for information only since they are not considered as currently viable control options (see Section 4.2).

4.3.2 Electrodeposition of Water-Based Coating

The electrodeposition process (EDP), as described in Section 4.2.1, has four potential sources of solvent emissions: the newly coated object as the coating is baked and evaporated, the surface of the coating in the EDP tank, the cascading rinse water, and the ultrafilter permeate sent to the drain. An approximate distribution of emissions for various sources is presented here to complete the discussion.

Most EDP coatings are supplied with a solvent-to-solids ratio of 0.06 to 0.12 by weight. The coatings on the substrates are about 95 percent solids when they emerge from the bath. The remaining 5 percent is predominantly water, with only 3 to 5 percent of the volatile fraction being solvent.[89] Therefore, solvent emissions from this source are relatively minor.

A more significant source of fugitive emissions is evaporation of solvent from the rinse water. During operation, a portion of the coating from the EDP tank is pumped through an ultrafilter (Figure 4-1). The permeate or excess water is used for rinsing, while the coating concentrate is returned to the EDP tank. Since ultrafiltration passes any compound having a molecular weight less than 500, a significant portion of water-miscible solvents, such as alcohols and glycol ethers, end up in the permeate.[89,90,91] These solvents then readily evaporate when the permeate is used for spray rinsing. Depending on the water requirements for the recycle system, some of the permeate may be wasted to the drain. This affords the liquid a period of time with open surface for solvent volatilization and subsequent discharge to the atmosphere.

Although emissions from the bath surface have not been quantified, based on analysis of a coating used at General Motors, the amount of organic solvent added to the bath will contribute 0.1 kg VOC/liter of applied solids.

4.3.3 Water-Based Spray

As described in Sections 4.2.1.2 and 4.2.1.3, water-based spray for surfacer and topcoat operations is currently being used to minimize VOC emissions. Use of these sprays is generally one of the first options considered to replace solvent-based sprays on the final coatings. In determining emission reductions for water-based spray coatings, it is necessary to consider the solvent content and solids content of the coating. In addition, transfer efficiency must be considered for the water-based coating and the solvent-based coating that it is replacing.

As a comparison, two water-based sprays of different water to organic solvent ratio (82/18 and 88/12) are contrasted against conventional enamel and lacquer (see Table 4-2). If a 25 volume percent solids water-based coating with an 82/18 water/solvent ratio by volume applied by air spray were used to replace a 28 volume percent solids solvent-based enamel, also applied by air spray, emissions would be reduced 79 percent. When compared to a 16 volume percent enamel, the potential reduction increases to nearly 90 percent.

Either reduction calculation is developed by first computing the ratio of solvent to solids content of each coating material and then dividing by the transfer efficiency for each application method to determine the total solvent per unit volume of coating applied. Percent reduction is determined from the VOC for the solvent-based lacquer minus the water-based coating divided by the VOC for the solvent-based lacquer. As an illustration a vehicle coated with 28 percent solids topcoat solvent-based enamel requires 3.41 liters of solids (see page 3-36) and 8.76 liters of solvent. At a typical solvent density of 0.839 kg/ℓ, this is equivalent to 2.16 kilogram VOC/liter solids sprayed. With a 40 percent transfer efficiency, the solids deposited would be 1.36 liters (0.4 x 3.41ℓ). Assuming that the same amount of solids would be deposited by a 25 percent solids water-based coating, its solvent content would be

TABLE 4-2. THEORETICAL EMISSION REDUCTION POTENTIAL ASSOCIATED WITH VARIOUS NEW COATING MATERIALS FOR USE AS AUTOMOTIVE BODY COATINGS

Coating Type and Percent Solids By Volume	Application Method	Transfer Efficiency, Percent	Solvent/Dry Solids Applied ℓ/ℓ	Potential Percent Emission Reduction When Replacing:	
				Lacquer, 16 v/o solids	Enamel, 28 v/o solids
Solvent-based enamel, 28 v/o[a]	Air spray	40	6.4	51	--
Solvent-based lacquer, 16 v/o	Air spray	40	13.1	--	--
Powder coating, 97 v/o	Electrostatic spray	98	0.03	99+	99+
Water-based	Electro-deposition	96	0.12	99	98
Water-based,[b] 25 v/o	Air spray	40	1.3	90	79
Water-based,[c] 25 v/o	Electrostatic spray	87	0.39	97	94

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[a] v/o = volume percent.
[b] Assumed 82/18 water/organic solvent ratio by volume.
[c] Assumed 88/12 water/organic solvent ratio by volume.

calculated as follows. The volumetric solvent-to-solids ratio for a 82/18 water to organic coating would be 0.54 (0.18 x 0.75 ÷ 0.25). When air sprayed at 40 percent efficiency, the 3.41 liters of solids would be carried in 1.84 liters of organic solvent (3.41 x 0.54) and is equivalent to 0.453 kilograms VOC/liter solids applied (0.839 x 0.54). The emission reduction would be 79 percent, based on two values for mass of VOC/liter solids applied ((2.16 - 0.453) x 100 ÷ 2.16).

The standards development has utilized this approach with specific coating material composition to determine VOC (measured as carbon) emissions. Emission limits were not determined from stack sampling but from coating formulations and the assumption that all VOC in the coating material is released to the atmosphere. Appendix C contains the equation used to determine the mass of volatile carbon per unit of coating solids. Data from a composite of 25 General Motors water-based topcoats yielded a relative solvent content of 0.34 kilogram VOC (measured as carbon) per liter solids in the coating material. This carbon/solids ratio must be divided by the transfer efficiency (40 percent for air spray) to determine the emissions per liter coating solids applied.

General Motors estimates that when using an acrylic lacquer topcoat, its two plants at Van Nuys and South Gate emitted a total of 5.31 million kilograms (11.70 million pounds) of solvent per model year from topcoat alone. When these plants converted to water-based topcoats, the emissions from the topcoating operations were reduced to 1.30 million kilograms (2.86 million pounds).[27] This represents an emission reduction of approximately 75 percent and agrees well with the theoretical results presented in Table 4-2.

One coating supplier estimated that an emission reduction in the range of 72 to 84 percent will result from substituting water-based for solvent-based enamels in spray applications.[19] His estimates, which were based on solvent-based coatings of 30 percent volume solids and water-based coatings of 18 to 33 percent organic solvent, also agree with the results above.

4.3.4 Powder Coating -- Electrostatic Spray

Powder coatings are nearly 100 percent solids. Thus, with only a small amount of volatile organic material, usually less than half of one percent,[92] powder coatings can be used to accomplish a large emission reduction. Although powders contain little volatile material, 2 to 3 percent of the coating solids can be emitted during baking of the polyvinyl chloride and epoxy coat. This material comes from the partial evaporation of plasticizers and coreactants.[93] Such values translate into a VOC emission rate per unit of applied coating of 0.020 to 0.031 kg/ℓ (at an assumed 98 percent transfer efficiency).

When powder coatings are electrostatically sprayed, the powder that does not deposit on the part is contained mostly in the spray booth. With properly designed equipment, if the over-sprayed powder is recovered, overall transfer efficiencies can be as great as 98 percent. This level is difficult to reach for automobile or light-duty truck coatings because of the many colors and the difficulty of segregating overspray from different colors.

4.3.5 Higher Solids Coatings

To determine the emission reduction potential associated with higher solids coatings, the VOC emission rate per unit of applied coating was determined for various points with solids content in the range of 30 to 80 volume percent. This emission rate was compared against those of both lacquer and solution enamel topcoats. These data are presented for two groups of substituted coatings in Figures 4-6 and 4-7. In preparing these estimates, two different transfer efficiencies were considered. Emissions from application by air spray (50 percent transfer efficiency) and electrostatic spray (80 percent transfer efficiency) were each compared with that from applying conventional solvent-based paints with air spray. Transfer efficiencies selected are representative of typical highly efficient systems.

As can be seen in Figure 4-6, if a 16 volume percent solvent-based lacquer were replaced by a 35 volume percent solids NAD or solution enamel applied by electrostatic spray, potential emission reduction would be nearly 80 percent.

At the present, most high-solids coatings are being developed to achieve 70 percent solids or greater. If the above solvent-based lacquer were replaced by only a 50 to 60 percent high-solids coating applied by air spray, then a potential emission reduction of over 80 percent could be realized. With the relatively high level of solvent dilution that would be associated with a 50 to 60 volume percent high-solids coating, such coatings could conceivably be sprayed without heated equipment and with relatively little modification of existing equipment.

Figure 4-7 shows that if a 28 volume percent NAD coating was replaced by a higher solids coating of 60 volume percent solids, then an emission reduction of 74 or 84 percent would be possible, depending on the method of application.

To show the benefit that could be obtained by developing this technology further, an example of a very high-solids coating is presented. If an 80 volume percent high-solids coating were used to

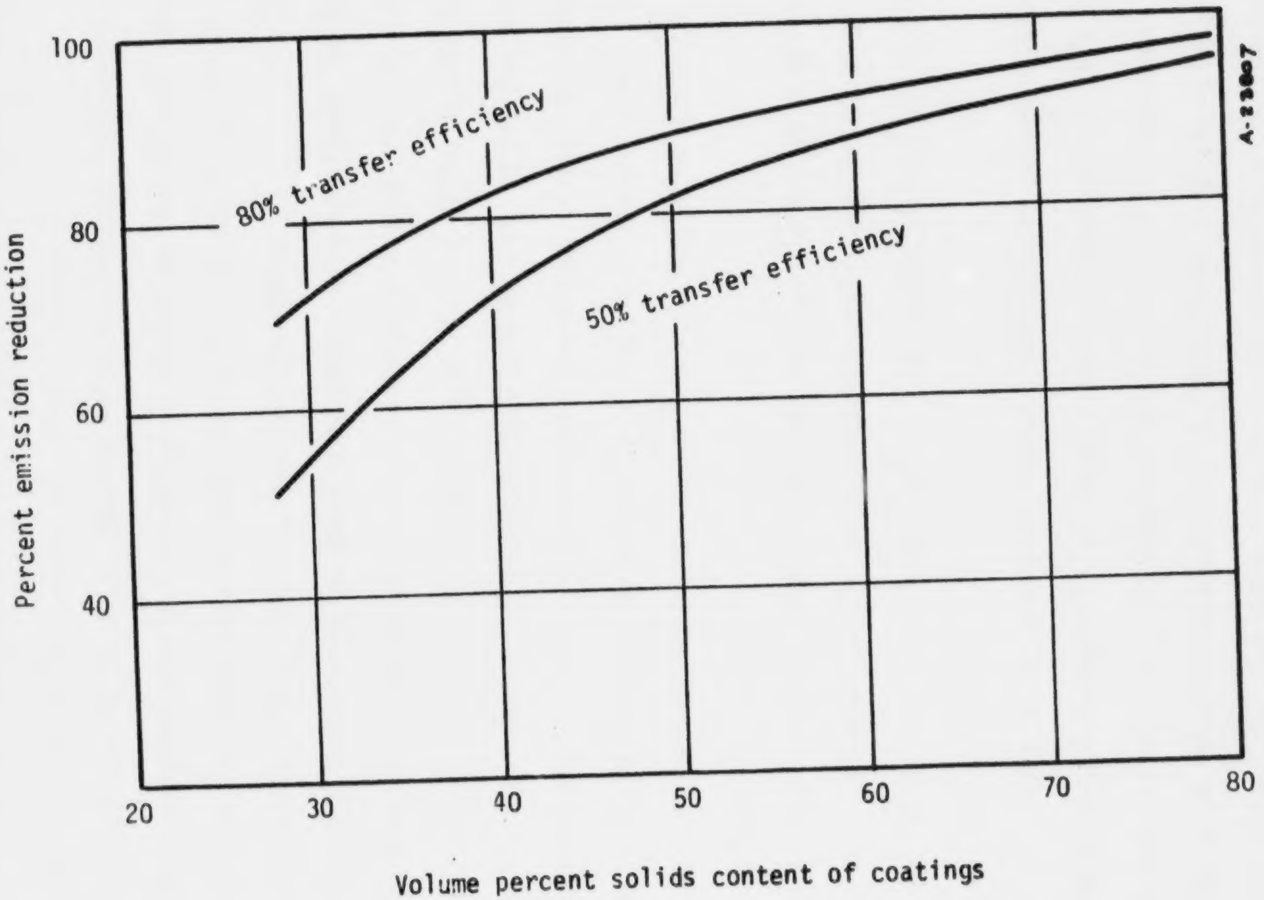

Figure 4-6. Emission reduction potential (percent) versus solids content of higher solids coatings replacing 16 volume percent lacquers at 50 percent transfer efficiency.

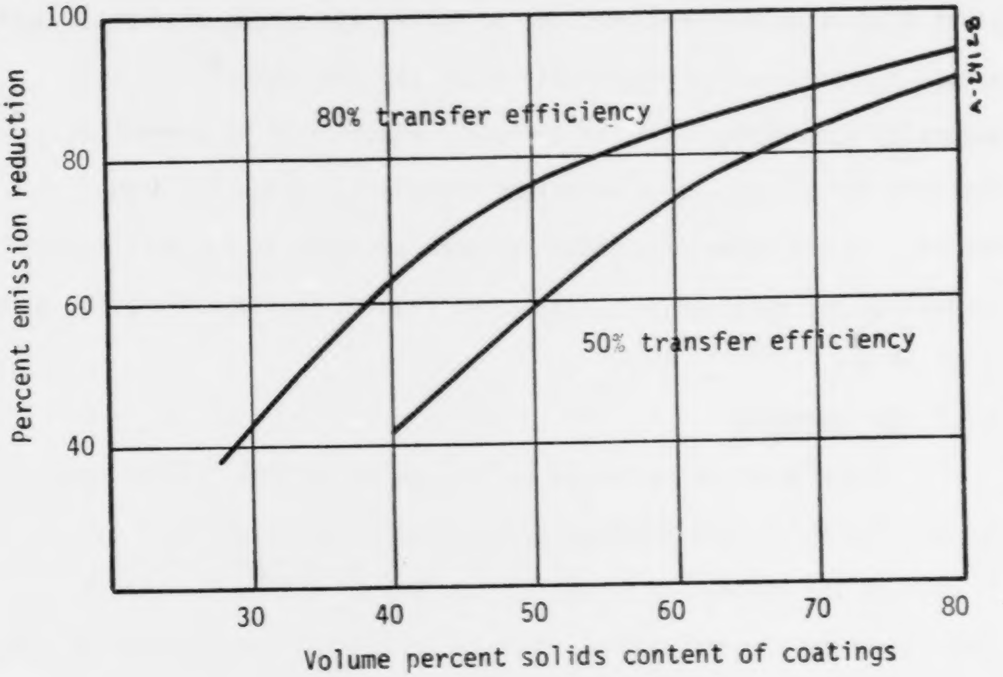

Figure 4-7. Emission reduction potential (percent) versus solids content of higher solids coatings replacing a 28 volume percent enamel at 50 percent transfer efficiency.

replace a 16 volume percent solvent-based lacquer, then an emission reduction as great as 95 percent would be possible.

4.3.6 Carbon Adsorption

Carbon adsorption is being used successfully in the paper and fabric industry for controlling solvent emissions.[94,95,96,97] Although pilot studies have been conducted, no full-scale carbon adsorption units are in place on auto or light-duty truck coating lines.[98] It is generally acknowledged that an emission reduction of 85 percent is possible for solvent vapor emissions from spray booths and ovens. However, in the automotive industry, such a system is not off-the-shelf technology and would be very costly and require considerable pilot work prior to use.[99,100,101]

4.3.7 Incineration

Incineration is currently being used to control solvent emissions in such finishing industries as paper, fabric, wire, can and coil coating, as well as the automotive finishing industry.[75-84,102-107] Field investigations of incinerators in these industries have documented that both thermal and catalytic incinerations are capable of eliminating 90 percent of the solvents from concentrated exhaust air streams.[80,84,104,105,108-110]

Conditions necessary for properly incinerating exhaust gases are discussed in Sections 4.2.5.1 and 4.2.5.2. As a summary of emission controls, state-of-the-art data from existing incinerators indicate that organic compounds are oxidized from 91 to 100 percent for inlet concentrations of 200 to 9000 ppm or 25 or more percent LEL.[104-111] The majority of these installations are on bake oven exhaust and receive concentrated airstreams. One investigator reported typical concentrations of organic solvents in the range of 30 to 300 ppm by volume in air from paint booths and 100 to 500 ppm by volume in air emitted from automobile assembly line baking ovens.[100]

No catalytic incinerators are routinely used in the automotive industry at this time.[86] Several bake ovens in Ford Motor Companyplants in California are equipped with thermal incinerators.[83,84,112] Typical units operating at 760° to 815°C (1400° to 1500°F) have operating efficiencies of at least 90 percent.[112]

Since existing systems are capable of oxidizing VOC above 90 percent, providing the temperature is adequate, the numerical emissions control is selected as 90 percent removal of VOC in the incinerated air stream of both bake oven and spray booth exhausts.

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5. MODIFICATIONS AND RECONSTRUCTIONS

5.1 BACKGROUND

This chapter identifies and discusses possible or typical changes to automobile and light-duty truck surface coating operations which could be termed modifications or reconstructions. Modified or reconstructed existing facilities must comply with standards of performance for new sources. A modification is defined as ". . . any physical change in, or change in the method of, operation of an existing facility which increases the amount of any air pollutant (to which a standard applies) emitted into the atmosphere by that facility or which results in the emission of any air pollutant (to which a standard applies) into the atmosphere not previously emitted."[1] An "existing facility" is defined as one which would be required to conform to a standard of performance, if it were new, but which was, in fact, constructed or modified before the date of proposal of the standard of performance.

The regulation on modifications requires the owner or operator of any source--an automobile and light-duty truck surface coating operation in this case--classified as an "existing facility" to notify EPA of changes which could cause an increase in emissions of an air pollutant for which a standard of performance applies.[2] These changes are not "modifications" (i.e., the existing facility would not have to meet the standards of performance) if the owner or operator demonstrates that no increase in emissions for which a regulation applied resulted from the alteration.

The term "reconstruction" is defined as the ". . . replacement of a substantial majority of the existing facility's components irrespective of any change of emission rate."[3] Reconstruction occurs when components of an existing facility are replaced to such an extent that:

- The fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and
- It is technologically and economically feasible to meet the applicable standards.

The purpose of this provision is to discourage the perpetuation of a facility which, in the absence of a regulation, would normally have been replaced.[4] The owner or operator must notify EPA to provide information concerning the construction or reconstruction of an existing facility.[5]

5.2 POTENTIAL MODIFICATIONS

The following potential modifications would apply to both passenger car and light-duty truck body painting operations, since both operations are similar. The only real difference is that automobile body lines generally run faster than light-duty truck lines. This difference, however, does not affect the types of changes that might be made to a coating line, the reasons for the change, or the nature of its impact on emissions. Therefore, for purposes of this chapter, the two operations can be considered similar.

Certain circumstances exist under which an increase in emissions does not result in a modification. If a capital expenditure less than the most recent annual asset guideline repair allowance published by the Internal Revenue Service (Publication 534) is made to increase capacity at an existing facility and also results in an increase in emissions of a regulated pollutant to the atmosphere, a modification is not considered to have occurred.[1]

The following changes in materials or formulations could increase solvent emissions but would be considered as a change in raw material and, therefore, not a modification.[1] If associated capital expenditures exceed the minimum for reconstructions, the facility could be considered to have been reconstructed and thus subject to the proposed regulation.

- Lower Solids Coatings. If a change is made from a higher to a lower solids coating (e.g., from an enamel to a lacquer), more material, and hence more solvent, will be used to maintain the same dry coating thickness. While a change in the direction of lower solids is unlikely, it could occur in any one plant as a result of changing paint systems, colors, models, or use of metallics. It is unlikely, however, that any major capital expenditures to equipment would be required.
- Use of Higher Density Solvent. Regulations normally restrict the number of pounds of solvent that can be emitted. An increase in the density of the solvents used, even if the volumetric amounts used were the same, would result in more mass of solvent being emitted. Again, this could be construed as a raw material substitution and hence not a modification, as no major capital expenditures would be involved. Such substitutions might come about as a result of solvent shortages, attempts to cut paint costs, or efforts to incorporate less photoreactive solvents.
- Increased Thinning of Coatings. A change to a higher viscosity coating could result in an increased use of solvents for thinning the coating to proper application consistency.

An increase in working hours (i.e., from one- to two-shift operation or from 8 hours to 10 hours per shift) does not increase solvent emissions per hour and, hence, is not considered a modification.[1]

Other possible changes that could result in increased solvent emissions include:

- Change to Larger Parts. If body size were increased, more coating materials could be used per vehicle, hence, emissions could increase even if production rates were maintained constant. While the overall trend is toward smaller sized automobiles, any one facility could switch from a smaller sized automobile to a larger model. It is felt, however, that such a change would not qualify as a modification per se, since automobile or light-duty truck assembly lines normally can accept more than one size of vehicle.
- Increased Film Thickness. A change to a thicker coating, if other factors remain constant, could result in increased solvent emissions. An effort is under way in the automotive industry to increase corrosion resistance, which could call for increased coverage or thicker coatings in corrosion-prone areas. If these changes are made only for the purpose of improved product reliability, and no increases in production rate occurs, they will will not be considered modifications.
- Reduced Deposition Efficiency. Increased overspray because of a process modification, such as a switch from electrostatic spray to conventional spray, would result in increased emissions. For economic reasons, however, a switch in such a direction is unlikely except possibly as a temporary measure.

- Additional Coating Stations. If for any reason additional coating stations were added, emissions could increase. Such a change would likely involve costly alterations or a new facility and, as such, would be subject to regulation.
- Annual Model Changeovers. Model changes are normally handled with existing equipment and do not require process changes.[6] Slight increases in emissions could occur, however, due to a change in configuration of the vehicle. For example, transfer efficiencies are usually lower for coating small vehicles than for larger ones. Therefore, a switch to production of smaller vehicles could cause an increase in emissions. However, such changes, made only for model changeovers and not intended to increase production rate, will not be considered modifications.
- Changes in Coating Specifications. Changes in coating materials to produce new colors or surfaces, increase corrosion resistance, or otherwise improve the quality of the surface coating, could be associated with an increase in solvent emissions.

Of the potential modifications listed above, only those involving production increases which require excessive capital expenditures will normally be considered as modifications. The installation of additional coating stations is the only change listed which would usually subject the source to regulation.

5.3 RECONSTRUCTIONS

Automotive spray booths and bake ovens usually last 20 to 25 years and are normally not replaced before that time unless process changes require their replacement.[6] When spray booth and bake oven replacements are made, however, the capital expenditures involved are normally sufficient to be considered reconstructions.

The trend toward electrodeposition (EDP) of water-based primer coatings may have an impact on the issue of reconstruction. Both Ford and General Motors use this system quite extensively, and Chrysler is now considering it.[6] International Harvester uses the system for priming light-duty truck bodies. Increased corrosion resistance is an advantage of the EDP coating system and a principal reason for its use; considerably lower solvent emissions (even with a guide coat) are an important secondary effect. Hence, if a primer paint line were to be replaced, an EDP system would likely be installed even without emission regulations. The fact that 50 percent of U.S. passenger car bodies are already prime-coated by this method would support such a conclusion. Installation of an EDP system, however, could be a potential reconstruction due to the costs involved in adding the tank, bake oven, and auxiliary equipment. Since EDP of water-based coatings achieves the lowest emissions of any control system identified in Chapter 4 for prime coat operations, any existing facility that changes to an EDP system should automatically meet a standard of performance.

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6. EMISSION CONTROL SYSTEMS

6.1 GENERAL

Chapter 4 described and evaluated the performance of the individual emission control technologies which can be used to reduce VOC emissions from coating operations in the automotive industry. This chapter identifies alternative emission control systems for typical automobile and light-duty truck surface coating operations. A system can be either a coating material and application technique, an add-on control device, or a combination of the two. The choice of the system depends on the particular coating operation and the desired level of control.

This chapter presents a number of alternative emission control systems to be used in analyzing the range of environmental (Chapter 7) and economic (Chapter 8) impacts associated with various alternative regulatory options. Primer, guide coat and topcoat operations are considered separate emission sources. Although there are many alternatives for controlling or reducing primer, guide coat, and topcoat emissions for both automobile and light-duty truck surface coating operations, only those shown in Table 6-1 were investigated. These were chosen because they are representative of the options available.

The model plant for automobile bodies produces 55 bodies per hour, 3,840 hours per year (basis: 240 days at two 8-hour shifts). The model plant for light-duty truck bodies operates at 38 bodies per hour, 3,840 hours per year. These model plants produce 211,200 automobiles or 145,920 light-duty trucks annually, and are typical of automotive assembly plants.

6.2 BASE CASE

The application of a water-based primer by cathodic electrodeposition (EDP) is currently in widespread use for the automobile and light-duty truck surface coating operations, primarily because of the increased corrosion protection it affords. Thus, cathodic EDP is considered the base case for the prime coat. At the present time, automobile and light-duty truck surface coating lines usually spray an additional coat on the vehicles between the primer and the topcoat. This additional coat, the primer surfacer, or guide coat, provides a smoother surface for the topcoat application. Most plants currently use solvent-based guide coat and topcoat, and, in the absence of air pollution regulations, new plants would likely continue this practice. Therefore, the use of organic solvent-based coatings is properly considered the base case for the guide coat and topcoat operations.

6.3 REGULATORY OPTIONS

There are three major sources of emissions from the coating of automobiles and light-duty trucks:

- Primer
- Guide coat
- Topcoat

For primer, EDP coating is the best control option and also the best coating. Therefore, as explained in Section 6.2, this can be considered the base case.

For guide coat and topcoat, two control methods are available:

- Use of water-based coatings
- Use of solvent-based coatings with incineration

Incinerators have been used by some automobile and light-duty truck plants for ovens, and, although not currently in use, incineration for spray booths presents no technical problem.[1-3]

The availability of these control methods leads to the three regulatory options described below:

- Regulatory Option I(A) involves EDP of water-based primer and the air spraying of water-based topcoat. When water-based topcoats are used, the surfacer used over the EDP primer is normally a water-based coating and is so assumed in this option. This option does not include any add-on controls.
- Regulatory Option I(B) adds incineration of the guide coat and topcoat emissions from the bake ovens to the base case. The incinerator achieves a 90 percent reduction in the VOC concentration of the stream passing through it.
- Regulatory Option II adds 90 percent effective incineration of the emissions from both the spray booths and ovens on the guide coat and topcoat operations to the base case.

Emissions from these options are summarized and compared to the base case in Table 6-1. Regulatory Options I(A) and I(B) achieve between 75 and 80 percent reduction from the base case, while Regulatory Option II achieves almost 90 percent reduction.

Table 6-1. AUTOMOBILE AND LIGHT-DUTY TRUCK SURFACE COATING OPERATIONS EMISSION CONTROL OPTIONS EVALUATED

Emission Control System	Emissions from Model Plant (Metric Tons/Year)		% Reduction From Base Case	
	Automobile	Light-Duty Truck	Automobile	Light-Duty Truck
Base Case 1. Primer - water-based coatings applied by EDP 2. Guide coat - solvent-based coatings applied by air spray 3. Topcoat - solvent-based coatings applied by air spray	1775	1273	--	--
Regulatory Option I(A) 1. Primer - water-based coatings applied by EDP 2. Guide coat - water-based coatings applied by air spray 3. Topcoat - water-based coatings applied by air spray	373	278	79	78
Regulatory Option I(B) 1. Primer - water-based coatings applied by EDP 2. Guide coat - solvent-based coatings applied by air spray with incineration of exhaust from ovens[1] 3. Topcoat - solvent-based coatings applied by air spray with incineration of exhaust from ovens[1]	435	301	76	76
Regulatory Option II 1. Primer - water-based coating applied by EDP 2. Guide coat - solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust[1] 3. Topcoat - solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust[1]	212	147	88	88

[1] Emissions based on incineration with 90% efficiency.

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7. ENVIRONMENTAL IMPACT*

7.1 AIR POLLUTION IMPACT

7.1.1 General

Automobile and light-duty truck assembly lines are major point sources of solvent emissions, most of which result from surface coating operations. These coatings are normally based on organic solvent which is released upon drying.

In 1973 (a very high production year), total U.S. consumption of paints and coatings was about 1,900,000 tonnes or 4,180 million pounds and consisted of the following solvent distribution:

Category	Tonnes ($\times 10^3$)	Percent
Oxygenated solvents	801	42
Aliphatic hydrocarbons	680	36
Aromatic hydrocarbons	400	21
Other	17	1
Total	1898	100

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*The incremental impacts discussed in this chapter were determined by comparing the various regulatory options to a base case consisting of a cathodic EDP system, a solvent-based guide coat, and a solvent-based topcoat. This base case system was considered to be typical of systems which industry might use in the absence of a new source performance standard. Shortly before proposal of the standards, a new EDP coating material was developed and placed in production use in at least two assembly plants. The new coating material is much lower in solvent content than the one used in this document for the regulatory options. Since the proposed standards are based on the use of the new EDP coating material, impacts of the proposed standards may vary slightly from those presented in this document.

In 1973, excluding maintenance coatings and exports, 1247 million liters (330 million gallons) of industrial finishes were made and applied on a variety of products.[1] Of this 1247 million liters of coatings, approximately 245 million liters (65 million gallons) were used in the automotive industry in the following distribution:

	Liters ($\times 10^6$)	Gallons ($\times 10^6$)	Percent
Automobiles	170	45	70
Light-Duty Trucks	40	10.5	16
Other Transportation	35	9.5	14
Total	245	65.0	100

The solvent fraction included in the total 1247 million liters of industrial product finishes is estimated at about 756 million liters (200 million gallons) or 61 percent. The solvent fraction of coatings used in the automotive industry varies from less than 2 percent to more than 90 percent depending on the type of coating used.

Solvent emissions from the automotive industry occur at the application and cure steps of the coating operation. For example, a typical automobile assembly line producing 211,200 vehicles per year (55 cars/hr, 16 hr/day, 240 days/year) creates uncontrolled volatile organic emissions from solvent-based primer of approximately 1000 tonnes (2,200,000 pounds) per year. Emissions from solvent-based topcoat operations of this line add about 1500 tonnes (3,300,000 pounds) per year. At this rate, slightly more than

10.4 tonnes (23,000 pounds) of solvent emissions are generated each work day from the total surface coating operation. Similarly, for a typical light-duty truck surface coating operation, approximately 7.2 tonnes (16,000 pounds) of solvent are emitted daily.

The objective of performance standards for new sources is to limit the emission of pollutants by imposing standards that reflect the degree of emission reduction achievable through the application of the best system(s) of emission reduction, that is (are) determined by the Administrator to be adequately demonstrated in achieving such reduction. Several alternative solvent emission control systems (hereinafter referred to as regulatory options) have been identified for automobile and light-duty truck surface coating operations.

To assess the environmental impact and the degree of emission control achieved by each alternative that could serve as the basis for standards, the emissions for these alternatives are compared. Also, other facets of environmental impact--such as potential water pollution and solid waste generation--are assessed. Similarly, State regulations and controlled emissions should be considered. These are discussed in the following paragraphs.

7.1.2 State Regulations and Controlled Emissions

In August 1971, Los Angeles County, California, adopted Rule 66 which controlled organic compound emissions. In 1976, Rule 66 was supplanted by South Coast Air Pollution Control District (SCAPCD)* Rule 442 with similar provisions. Rule 442 states that emissions of photochemically reactive solvents** are not to exceed 18 kilograms (39.6 pounds) per day and emissions of nonphotochemically reactive solvents are limited to 1350 kilograms (2970 pounds) per day. Emissions from organic materials that come into contact with flame or are baked are limited to 6.5 kilograms (14.3 pounds) per day. Emissions above these limits are subject to 85 percent emission control. The regulation also provides exemptions for water-based coatings where the volatile content consists of 80 percent water.

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* Replaced by the South Coast Air Quality Management District (SCAQMD) on February 1, 1977.

As of 1977, 13 States had statewide regulations dealing with hydrocarbon emissions. Approximately half of these States' regulations were the same as or similar to Rule 442 (Rule 66) of the SCAQMD. These regulations carefully limited the amount of photochemically reactive solvent volatiles that could be emitted within a given time period from coating applications, baking ovens, and curing operations in an automotive plant.

** Photochemically reactive solvent means any solvent with an aggregate or more than 20 percent of its total volume composed of the chemical compounds classified below or which exceeds any of the following individual percentage composition limitations, referred to the total volume of solvent:

a. A combination of hydrocarbons, alcohols, aldehydes, ethers, esters, or ketones having an olefinic of cycloolefinic type of unsaturation except perchloroethylene: 5 percent

b. A combination of aromatic compounds with eight or more carbon atoms to the molecule excpet ethylbenzene, methylbenzoate, and phenyl acetate: 8 percent

c. A combination of ethylbenzene, ketones having branched hydrocarbon structures, trichloroethylene or toluene: 20 percent

Whenever any organic solvent or any constitutent of an organic solvent may be classified from its chemical structure into more than one of the above groups of organic compounds, it shall be considered as a member of the most reactive chemical groups, that is, that group having the least allowable percent of the total volume of solvents.

There are many difficulties in understanding and interpreting Rule 442-type regulations. Among those States having this type of regulation, there are many variations and different interpretations of requirements. There has been considerable debate over what constitutes a photochemically reactive solvent and a nonphotochemically reactive solvent at both the State and Federal levels. The situation is further complicated by the fact that the States are currently rewriting their regulations.

7.1.3 Comparative Emissions from Model Plants Employing Various Operating Options

The various options that have been considered in this document and discussed in Chapter 4 are summarized in Table 7-1. Comparative emissions of model plants utilizing these options were determined for enamel coating assembly lines.

7.1.3.1 Automobiles

A model assembly line representative of typical new lines in industry produces 55 automobiles per hour and operates two 8-hour shifts per day. This line produces 880 autmobiles per day or 211,200 automobiles per year (240 work days per year). Table 7-2 lists uncontrolled and controlled emissions from this model assembly line. This model does not represent a specific plant line nor is it intended to include all parameters of such lines.

The solvent-based spray primer case described in Chapter 3 (Table 3-10), based on typical coating application rates and solids content, results in approximatley 1020 tonnes (2,244,000 pounds) of solvent emission per year. The conveying organic solvent, 5.71 liters per vehicle (Table 3-13), was assumed to completely discharge to the atmosphere. At 24 volume percent

Table 7-1. OPERATING OPTIONS

Spray Technology Case* (No add-on controls)

Primer -- solvent-based coatings applied by air spray
Topcoat -- solvent-based coatings applied by air spray

Base Case

Primer -- water-based coatings applied by EDP
Guide coat -- solvent-based coatings applied by air spray
Topcoat -- solvent-based coatings applied by air spray

Regulatory Option I(A)

Primer -- water-based coatings applied by EDP
Guide coat -- water-based coatings applied by air spray
Topcoat -- water-based coatings applied by air spray

Regulatory Option I(B)

Primer -- water-based coatings applied by EDP
Guide coat -- solvent-based coatings applied by air spray
Topcoat -- solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust

Regulatory Option II

Primer -- water-based coatings applied by EDP
Guide coat -- solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust
Topcoat -- solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust

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*Spray transfer efficiency is assumed to be 43 percent in all options.

Table 7-2. UNCONTROLLED AND CONTROLLED EMISSIONS FROM AUTOMOBILE SURFACE COATING OPERATIONS

(tonnes/year)

Spray Technology Case (No add-on controls)		
Primer -- solvent-based		1020
Topcoat -- solvent-based		1489
	Total	2509
Base Case		
Primer -- EDP water-based coatings		37
Guide coat -- solvent-based coatings		249
Topcoat -- solvent-based coatings		1489
	Total	1775
Regulatory Option I(A)		
Primer -- EDP water-based coatings		37
Guide coat -- water-based coatings		41
Topcoat -- water-based coatings		295
	Total	373
Regulatory Option I (B)		
Primer -- EDP water-based coatings		37
Guide coat -- solvent-based coatings		249
Topcoat -- incinerated solvent-based coatings		149
	Total	435
Regulatory Option II		
Primer -- water-based coatings		37
Guide coat -- incinerated solvent-based coatings		26
Topcoat -- incinerated solvent-based coatings		149
	Total	212

solids, 1.82 liters of solids are sprayed, 43 percent of which are applied to the vehicle and the remainder are oversprayed. For the base case, a prime coating was applied by EDP followed by an air-sprayed guide coat of 24 volume percent organic solvent. The EDP coating was assumed to contain 4 volume percent solvents, which at an average application rate of 5.30 liters per vehicle (1.4 gal/ vehicle) results in 37 tonnes (81,400 pounds) of solvent emissions per year for the EDP step.[2] The solvent guide coat was applied by air spray at an application rate of 1.4 liters/solvent emission per vehicle, which results in an additional 249 tonnes (547,800 pounds) per year solvent emissions:[2]

$$1.4\ell/\text{veh} \times 211{,}200\ \text{veh/yr} \times 0.839\ \text{kg}/\ell \times 10^{-3}\ \text{tonnes/kg} = 249\ \text{tonnes/yr}$$

Regulatory Option I(B) employed incineration of bake oven and spray booth exhaust for the topcoat, while the guide coat and topcoat would both be organic solvent based. Incineration was assumed to provide 90 percent removal of the VOC emitted. A similar percentage removal of the guide coat VOC was assumed for Regulatory Option II.

7.1.3.2 Light-Duty Trucks

The model light-duty truck assembly line produces 145,920 bodies per year (in 240 work days). As in the automobile base case, the model being discussed here does not represent a specific line nor is it intended to indicate that all light-duty truck surface coating operations have these parameters. Table 7-3 shows uncontrolled and controlled emissions from this model light-duty truck assembly line for the options listed in Table 7-1. Emission control for the light-duty truck industry segment was determined by the same approach as for the automobile segment. Primers of 30 percent solids by volume and 28 percent for topcoat were selected.

Table 7-3. UNCONTROLLED AND CONTROLLED EMISSIONS FROM LIGHT-DUTY TRUCK SURFACE COATING OPERATIONS

(tonnes/year)

Spray Technology Case (No add-on controls)		
Primer -- solvent-based		649
Topcoat -- solvent-based		1080
	Total	1729
Base Case		
Primer -- EDP water-based coatings		21
Guide coat -- solvent-based coatings		172
Topcoat -- solvent-based coatings		1080
	Total	1273
Regulatory Option I(A)		
Primer -- EDP water-based coatings		21
Guide coat -- water-based coatings		28
Topcoat -- water-based coatings		229
	Total	278
Regulatory Option I(B)		
Primer -- EDP water-based coatings		21
Guide coat -- solvent-based coatings		172
Topcoat -- incinerated solvent-based coatings		108
	Total	301
Regulatory Option II		
Primer -- water-based coatings		21
Guide coat -- incinerated solvent-based coatings		18
Topcoat -- incierated solvent-based coatings		108
	Total	147

7.1.4 Estimated VOC Emission Reduction in Future Years

7.1.4.1 General

After a record production of 9.7 million automobiles in 1973, sales declined in 1974 and 1975. In 1976, the auto industry staged a comeback and production returned to over 8 million automobiles, with further gains in 1977 to greater than 9 million. A recent study estimates U.S. production will be approximately 11 million units in 1985.[3]

As with the automobile industry, the truck industry was affected by the recession. After the record production of 3,007,495 units in 1973, production slackened in 1974 and 1975. However, truck production in 1976 increased 37 percent over 1975 production and exceeded the record high of 1973 by about 8000 units.[4,5] Short-range (to 1983) expansion rates are projected at approximately 4 percent per annum. Based on these growth figures and the above estimate that light-duty truck production accounts for 75 percent of total truck production, the manufacture of these vehicles is expected to reach 2.54 million in 1979, 2.65 million in 1980, and 2.98 million in 1983.[6]

7.1.4.2 Automobiles

In 1979, approximately 9.6 million automobiles were manufactured in the U.S. As stated in Chapter 4, it is expected that two new automobile assembly lines will be added to meet the expected production rate of 10.87 million automobiles in 1983.

To determine the impact of VOC emission reduction by new standards of performance, an industry-wide emission scenario was developed. For the 1979 base case, it was assumed that 40 percent of the lines use solvent-based primer and 60 percent use water-based primer. All indications are that the automobile industry recognizing the technological merits of EDP of water-based primer will tend to continue to use water-based primers in increasing amounts. As this would occur even without air pollution control regulations, the base case represents a continuation of state-of-the-art technology. In Regulatory Option I(A), both new lines are assumed to be water-based for guide coat and topcoat systems. In Regulatory Option I(B), the new lines would use incineration of the solvent-based topcoat emission. For Regulatory Option II, these new lines are expected to have incineration on both the guide coat and topcoat spray booth and oven exhausts. As shown in Table 7-4, Regulatory Option I(A) would cause a decrease in emissions amounting to approximately 2,804 tonnes (6,168,800 pounds) per year. Emission values for this scenario were taken from Table 7-2.

7.1.4.3 Light-Duty Truck

As with automobiles, it is assumed that EDP of water-based primer will be the preferred primer technology for new surface coating lines even if no controls are used. The data presented in Table 7-3 are based on the assumption that 145,920 trucks are manufactured per line per year. In 1979, 2.54 million light-duty trucks were manufactured. With the addition of two new light-duty truck assembly lines by 1983, it is expected that manufacture of these vehicles will increase to 2.98 million. Table 7-5 presents the projected emission impacts for 1979 and 1983 produced by the various regulatory options as discussed in Section 7.1.4.1. Regulatory Option I(A) would cause a projected decrease of approximately 2000 tonnes (4,400,000 pounds) per year in solvent emissions.

TABLE 7-4. AUTOMOBILE EMISSIONS PROJECTIONS[a] (tonnes per year)

	Model Assembly Line Emissions	1979 Emissions	1983 Emissions			
		Base Case	Base Case	Regulatory Option I(A)	Regulatory Option I(B)	Regulatory Option II
Primer						
Solvent-based	1,020	18,360	18,360	18,360	18,360	18,360
EDP Water-based	37	999	1,073	1,073	1,073	1,073
Subtotals		19,359	19,433	19,433	19,433	19,433
Guide Coat[b]						
Solvent-based	249	6,723	7,221	6,723	7,221	6,723
Water-based	41			82		
Incinerated Solvent-based	26					52
Subtotals		6,723	7,221	6,805	7,221	6,775
Topcoat						
Solvent-based	1,489	67,005	69,983	67,005	67,005	67,005
Water-based	295			590		
Incinerated Solvent-based	149				298	298
Subtotals		67,005	69,983	67,595	67,303	67,303
TOTALS		93,087	96,637	93,833	93,957	93,511

[a] Assumes no effect of State or local regulations
[b] Used with electrodeposition only

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TABLE 7-5. LIGHT-DUTY TRUCK EMISSIONS PROJECTIONS[a] (tonnes per year)

	Model Assembly Line Emissions	1979 Emissions	1983 Emissions			
		Base Case	Base Case	Regulatory Option I(A)	Regulatory Option I(B)	Regulatory Option II
Primer						
Solvent-based	649	4,543	4,543	4,543	4,543	4,543
EDP Water-based	21	210	252	252	252	252
Subtotals		4,753	4,795	4,795	4,795	4,795
Guide Coat[b]						
Solvent-based	172	1,720	2,064	1,720	2,064	1,720
Water-based	28			56		
Incinerated Solvent-based	18					36
Subtotals		1,720	2,064	1,776	2,064	1,756
Topcoat						
Solvent-based	1,080	18,360	20,520	18,360	18,360	18,360
Water-based	229			458		
Incinerated Solvent-based	108				116	116
Subtotals		18,360	20,520	18,818	18,476	18,476
TOTALS		24,883	27,379	25,389	25,335	25,027

[a] Assumes no effect of State or local regulations

[b] Used with electrodeposition only

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The use of Regulatory Option I(A) for both automobile and light-duty truck operations results in an overall reduction in solvent emissions amounting to approximately 4800 tonnes (10,560,000 pounds) per year.

7.2 WATER POLLUTION IMPACTS

As the industry has changed its surface coating operations to minimize VOC emissions, increasing amounts of water have been used to transfer the solids. Minor discharges of wastewater from EDP dripping, spills during cleanup, and from spray booth removal of overspray are the primary liquid wastes.

7.2.1 Ultrafiltration

Water-based EDP primers are prepared by neutralizing highly acidic polymers with an alkali (e.g., amines) so that these polymers can be dissolved or suspended in water. Small amounts of solvents are also added to increase the dispersibility of polymers in water.

During EDP, the solids coat the automobile or light-duty truck body, leaving alkali coalescing solvents behind in the dip tank. These solvents must be removed. In modern installations, ultrafiltration is used to continuously remove water-solubles and chemical agents that are left behind during the process (see details in Section 7.3). Any effluent originating from a properly operated ultrafiltration unit can be adequately handled in municipal or in-house sewage treatment facilities. Low molecular weight compounds that pass through the ultrafiltration membrane do exert chemical oxygen demand (COD) as discussed in Chapter 4.

7.2.2 Dripping, Spills, and Cleanup

Water pollution can also occur if the electrocoating system allows rinse water or coating to drip or be spilled on the floor and the rinse and/or cleanup water is not automatically placed in a reservoir for treatment.

7.2.3 Dragout

At the end of the electrocoating operation, the dipped body is covered with an additional film of adhering paint called dragout. This film is more porous than the electrodeposited coating; therefore, it is usually rinsed off. Dragout also occurs as the body leaves the dip tank. Dragout is returned to the dip tank or the ultrafiltration system.

7.2.4 Overspray Removal

As mentioned in Chapter 4, guide coats and topcoats are both applied by spraying. Spraying operations are carried out in spray booths for which most automobile companies use waterwall washing to control overspray. In the spray booth, a portion of the total coating is deposited on the surface of the object being coated. The amount of coating not deposited on the object is called overspray. In a typical waterwall spray booth, the paint particles from overspray are collected by a curtain of water flowing down the face of a sheet of steel located at the rear sides of the booth--the so-called waterwalls. These waterwalls flow between 25 and 50 gallons per minute per foot.[7] Thus, a 20-foot section would have a waterflow of approximately 600 gallons per minute.[7] In actual practice, this means that a spray booth 180 feet long would need between 4500 and 9000 gallons of water per minute. A typical surface coating operation with four spray booths would need between 18,000 and 36,000 gallons of water per minute.[8] The used water is removed from the booth and transported to a sludge tank, where the solids are removed, and the water is recirculated. Air spray transfer efficiency varies from 30 to 60 percent.[9] This wide range results from the operation's efficiency being dependent on individual operators and the type of spraying technique used.

Solvent-based topcoats are composed primarily of solvents, which separate readily from water. Water-based topcoats, however, are made with water-miscible solvents to assure good suspension of the resin binder in the water phase of the coating. These various water-miscible solvents (glycols, and certain esters and alcohols) in water-based coatings are extremely miscible with water and actually act as coupling agents between suspended particles and water.

Solvents remaining in discharged water exert a COD. Chemical oxygen demand presents a problem, if it is discharged into a stream in sufficient concentration and quantity to diminish the oxygen in the stream, thereby, affecting fish and other aquatic life. Almost all assembly plants discharge spray booth effluent, following solids removal, to municipal sewers--some of which have restrictions on COD. The effluent from two General Motors plants using water-based topcoats is acceptable to sewer authorities. If necessary, techniques can be used to lower the COD.

No water pollution impact is associated with the other emission control systems considered as options.

7.3 SOLID WASTE DISPOSAL IMPACT

Water-based primer EDP operations can have impact on solid waste disposal. In older installations the dragout and rinse were discarded, resulting in a waste disposal problem. This practice also caused coating loss. Improvements have been made, however, to reduce coating loss by returning the coating to the dip tank.

In modern operations, ultrafiltration continuously removes the amine(s), solvents, and water-solubles, which are left behind during the electrocoating. Consequently, it is possible to set up a nearly closed system with practically no waste.

Once a year there is a regular cleaning of the ultrafiltration system. Otherwise, cleaning is not needed except on such occasions as when a paper cup or other foreign object is accidently dropped into the dip tank. Such a minor cleaning job, however, does not involve dumping more than a few gallons of paint.

There are no serious waste disposal problems associated with electrocoating. Sludge may develop in the dip tank, leading to a minor solid waste disposal problem; however, sludge is generally the result of improperly controlled chemistry in the tank or poor housekeeping (such as allowing parts to accumulate in the tank). In any case, the amount of such solid waste is not excessive.

While water-based primers no longer present serious sludge and solid waste disposal problems, water-based topcoats are prone to do so. Water-based topcoats, because they are partial or full suspension systems similar to dispersion and/or emulsions, display considerably less storage stability than do solvent-based topcoats, which are often actually true solutions. In a dispersion, fine particles (of the binder) are suspended in a continuous liquid phase such as water.

The stability of these suspension (also referred to as colloidal) systems is very dependent on the water-to-solvent ratio. This is especially true when the water-to-solvent ratio of a water-based topcoat is disturbed, as it is when the overspray or the water-based topcoat hits the spray booth waterwall. In the waterwall, a major portion of the water-based topcoat overspray is thrown out of suspension, forming lumps consisting of agglomerated solids with locked-in water. This significantly increases the amount of sludge formed in an automotive plant.[8,10]

Sludge formed during a conventional solvent-based topcoat operation--as for example a combined light-duty truck/automobile production of 50 units per hour each, working with two shifts--results in a daily amount of 15,000 to 20,000 pounds.[11] As an average, approximately four times more sludge is formed during water-based topcoat operations than is formed during solvent-based topcoat operations. For example, one of the automotive plants reported that its sludge tank had to be cleaned only once a year when using solvent-based topcoats, and when the plant switched to water-based topcoats, the sludge tank had to be cleaned every three months.[12] Estimates of the exact amounts and compositions of the sludge by various automotive industry spokesmen vary over a wide spectrum.

There are some basic differences between the treatment of sludge from solvent-based coatings and that of water-based topcoats. Sludge from water-based topcoats, in order to break the suspension system and to remove the particles, is treated with slightly acidic compounds like calcium acetate at a pH of 3 to 4.[13] Ultrafiltration could be used to remove colloidal particles, but this method is an expensive solution to the problem.[13] The heavy metals in pigments of some topcoating solids may require special disposal due to the potentially harmful nature of these materials.

However, the solid waste problem associated with the use of the water-based coatings is minor when compared with the solid waste considerations of the total automotive plant. Typical values for operations are given in Chapter 3, Table 3-14. There is little solid waste impact associated with alternatives other than water-based coatings.

7.4 ENERGY IMPACT

Automobile and light-duty truck surface coating operations consume significant amounts of energy. With the exception of catalytic incinerators--with primary and secondary heat exchangers used on the curing oven--all the regulatory options presented in this report require additional energy.

The energy impacts associated with each regulatory option are summarized in Tables 7-6 through 7-13. These tables are a compact representation and summary of energy balances prepared for the purpose of comparing the primary energy required for a base case finishing model to the primary energy required when pollution reduction coatings and/or add-on emission controls are used.

Standards based on Regulatory Option I(A) would increase the energy consumption of a typical new automobile and light-duty truck assembly plant by the equivalent of about 18,000 barrels of fuel oil per year--this amounts to an increase of approximately 25 percent. About one-third of this increase in energy consumption is due to the use of air conditioning, which is necessary with the use of water-based coatings, and the remaining two-thirds are due to the increased fuel required in the bake ovens for curing water-based coatings. Standards based on Regulatory Option I(B) would cause an increase of about 150 to 425 percent in energy consumption; this amounts to an increase of about 100,000 to 300,000 barrels of fuel oil per year. Standards based on Regulatory Option II would result in an increase of 300 to 700 percent; this is equivalent to about 200,000 to 500,000 barrels of fuel oil per year, depending upon whether catalytic or thermal incineration were used.

TABLE 7-6. ENERGY BALANCE -- BASE CASE MODEL AND PROCESS MODIFICATION

Automobile Body Primer Application

Model Description	Energy Requirements/211,200 Cars [a]			
	Primer Application	Primer Cure Oven		Total Energy Requirements
	Electricity kW/hr	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Solvent-borne primer spray	1,516,759	383,827	72,349	91,354[b]
Base case -- Electrodeposition of water-borne primer with solvent-borne surfacer[c]	7,339,035	756,045	142,350	223,300
Option to base case -- Electrodeposition of water-borne primer with water-borne surfacer[c]	8,052,420	997,660	162,600	253,101

[a] 211,200 cars -- the yearly output of a model surface coating operation

[b] Sample calculation: (1,516,759 kW/hr x 10,000 Btu/kW/hr) + (383,827 kW/hr x 10,000 Btu/kW/hr) + 72,349 x 10^6 Btu = 91,354 x 10^6 Btu.

[c] Energy values include energy associated with the surfacer.

TABLE 7-7. ENERGY BALANCE -- ADD-ON EMISSION CONTROL SYSTEMS

Automobile Body Primer Application

Model Description	Energy Requirements/211,200 Cars [a]				
	Emission Control Equipment				Total Energy Requirements
	Primer Application		Primer Cure Oven		
	Electricity kW/hr	Fuel 10^6 Btu	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Incinerator on oven only, 10% LEL					
Thermal -- primary heat exchanger	--	--	69,120	9,600	10,291
Thermal -- primary and secondary heat exchanger	--	--	80,640	3,070[b]	3,876
Catalytic -- primary heat exchanger	--	--	72,960	1,536	2,266
Catalytic -- primary and secondary heat heat exchanger	--	--	84,480	(2,304)[c]	(1,459)
Incinerator on spray booths only[d]					
Thermal -- primary heat recovery	2,977,920	1,267,200	--	--	1,296,979
Catalytic -- primary heat recovery	3,146,880	464,640	--	--	496,109

[a] 211,200 cars -- the yearly output of a model surface coating operation

[b] Energy credit from secondary heat recovery is included.

[c] The parentheses indicate that the shown amount of energy is a credit.

[d] Does not include energy for comfort heating of spray booth air.

TABLE 7-8. ENERGY BALANCE -- BASE CASE MODEL AND PROCESS MODIFICATION

Automobile Body Topcoat Application

Model Description	Energy Requirements/211,200 Cars [a]			
	Topcoat Application	Topcoat Cure Oven		Total Energy Requirements
	Electricity kW/hr	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Base Case -- Solvent-based spray topcoat	3,901,555	990,624	186,041	234,963
Option to Base Case -- Water-based spray topcoat	6,506,737	1,662,798	238,130	319,825

[a] 211,200 cars -- the yearly output of a model surface coating operation

TABLE 7-9. ENERGY BALANCE -- ADD-ON EMISSION CONTROL SYSTEMS

Automobile Body Topcoat Application

Model Description	Energy Requirements/211,200 Cars [a]				
	Emission Control Equipment				Total Energy Requirements
	Primer Application		Primer Cure Oven		
	Electricity kW/hr	Fuel 10^6 Btu	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Incinerator on oven only, 10% LEL					
Thermal -- primary heat exchanger	--	--	99,840	13,440	14,438
Thermal -- primary and secondary heat exchanger	--	--	115,200	3,840[b]	4,992
Catalytic -- primary heat exchanger	--	--	103,680	2,380	3,417
Catalytic -- primary and secondary heat heat exchanger	--	--	122,880	(3.380)[c]	(2,151)
Incinerator on spray booths only[d]					
Thermal -- primary heat recovery	4,060,800	1,728,000	--	--	1,768,608
Catalytic -- primary heat recovery	4,273,920	633,600	--	--	676,339

[a] 211,210 cars -- the yearly output of a model surface coating operation

[b] Energy credit from secondary heat recovery is included.

[c] The parentheses indicate that the shown amount of energy is a credit.

[d] Does not include energy for comfort heating of spray booth air.

TABLE 7-10. ENERGY BALANCE -- BASE CASE MODEL AND PROCESS MODIFICATION

Light-Duty Truck Body Primer Application

Model Description	Energy Requirements/145,920 Trucks[a]			
	Primer Application	Primer Cure Oven		Total Energy Requirements
	Electricity kW/hr	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Solvent-based primer spray	1,240,258	349,253	36,325	52,221
Base Case -- Electrodeposition of water-based primer water-based surfacer[b]	5,153,750	678,250	82,000	140,321
Option to Base Case -- Electrodeposition of water-based primer water-based surfacer[b]	5,812,760	818,240	92,100	158,410

[a] 145,920 trucks -- the yearly output of a model surface coating operation

[b] Energy values include energy associated with the surfacer.

TABLE 7-11. ENERGY BALANCE -- ADD-ON EMISSION CONTROL SYSTEM

Light-Duty Truck Body Primer Application

Model Description	Energy Requirements/145,920 Trucks[a]				
	Primer Application		Primer Cure Oven		Total Energy Requirements
	Electricity kW/hr	Fuel 10^6 Btu	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Incinerator on oven only, 10 % LEL					
Thermal -- primary heat exchanger	--	--	46,080	6,720	7,181
Thermal -- primary and secondary heat exchanger	--	--	53,760	2,120[b]	2,658
Catalytic -- primary heat exchanger	--	--	53,760	1,152	1,690
Catalytic -- primary and secondary heat exchanger	--	--	61,440	(960)[c]	(346)
Incinerator on spray booths only[d]					
Thermal -- primary heat recovery	1,739,904	748,800	--	--	766,199
Catalytic -- primary heat recovery	1,825,152	278,784	--	--	299,035

[a] 145,920 trucks -- the yearly output of a model surface coating operation

[b] Energy credit from secondary heat recovery is included.

[c] The parentheses indicate that the shown amount of energy is a credit.

[d] Does not include energy for comfort heating of spray booth air

TABLE 7-12. ENERGY BALANCE -- BASE CASE MODEL AND PROCESS MODIFICATION

Light-Duty Truck Body Topcoat Application

Model Description	Energy Requirements/145, 920 Trucks[a]			
	Primer Application	Primer Cure Oven		Total Energy Requirements
	Electricity kW/hr	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Base Case				
Solvent-based spray topcoat	3,179,607	898,329	93,405	134,184
Option to Base Case				
Water-based spray topcoat	5,314,920	1,499,080	96,291	164,431

[a] 145,920 trucks -- the yearly output of a model surface coating line

TABLE 7-13. ENERGY BALANCE -- ADD-ON EMISSION CONTROL SYSTEM

Light-Duty Truck Body Topcoat Application

Model Description	Energy Requirements/145,920 Trucks[a]				
	Primer Application		Primer Cure Oven		Total Energy Requirements
	Electricity kW/hr	Fuel 10^6 Btu	Electricity kW/hr	Fuel 10^6 Btu	10^6 Btu
Incinerator on oven only, 10 % LEL					
Thermal -- primary heat exchanger	--	--	69,120	9,600	10,291
Thermal -- primary and secondary heat exchanger	--	--	80,640	3,070[b]	3,876
Catalytic -- primary heat exchanger	--	--	72,960	1,536	2,266
Catalytic -- primary and secondary heat exchanger	--	--	84,480	(2,304)[c]	(1,459)
Incinerator on spray booths only[d]					
Thermal -- primary heat recovery	2,977,920	1,267,200	--	--	1,296,979
Catalytic -- primary heat recovery	3,134,208	464,640	--	--	495,982

[a] 145,920 trucks -- the yearly output of a model surface coating operation
[b] Energy credit from secondary heat recovery is included.
[c] The parentheses indicate that the shown amount of energy is a credit.
[d] Does not include energy for comfort heating of spray booth air

The relatively high impact of standards based on Regulatory Option I(B) and Regulatory Option II is due to large amounts of incineration fuel needed.

As previously stated, growth projections indicate that four new assembly lines (two automobile and two light-duty truck lines) will be built by 1983. Based on these projections, standards based on Regulatory Option I(A) would increase national energy consumption in 1983 by the equivalent of about 72,000 barrels of fuel oil. Standards based on Regulatory Option I(B) would increase national energy consumption in 1983 by the equivalent of 400,000 to 1,200,000 barrels of fuel oil, depending upon whether catalytic or thermal incineration were used. Standards based on Regulatory Option II would increase national energy consumption in 1983 by the equivalent of 800,000 to 2,000,000 barrels of fuel oil, again depending upon whether catalytic or thermal incineration were used.

Table 7-14 presents a summary of the primary energy requirements of each option and the incremental increase for each option.

7.5 OTHER ENVIRONMENTAL IMPACTS

No other environmental impacts are likely to arise from standards of performance for automobile or light-duty truck surface coating operations, regardless of which alternative emission control system is selected as the basis for standards.

7.6 OTHER ENVIRONMENTAL CONCERNS

7.6.1 Irreversible and Irretrievable Commitment of Resources

The alternative control systems will require the installation of additional equipment, regardless of which alternative emission control system is selected. This will require the additional use of steel and other resources. This commitment of resources will be small compared to

TABLE 7-14. SUMMARY OF ENERGY REQUIREMENTS FROM REGULATORY OPTIONS

Automobile Line	Energy Requirements	Incremented Increase	Base
Option I(A)	10^6 Btu	10^6 Btu	10^6 Btu
Primer -- EDP Water-based Guide Coat -- EDP Water-based	253,101	29,801	223,300
Topcoat -- EDP Water-based	319,825	84,862	234,963
Option I(B)			
Primer -- EDP Water-based Guide Coat -- Solvent-based	223,300	0	223,300
Topcoat -- Solvent-based with incineration			
Thermal	2,008,563	1,773,600	234,963
Catalytic	909,151	674,188	234,963
Option II			
Primer -- EDP Water-based	223,300	1,795,505	223,300
Guide Coat -- Solvent-based with incineration			
Thermal	1,300,855	1,300,855	0
Catalytic	494,650	494,650	0
Topcoat -- Solvent-based with incineration			
Thermal	2,008,563	1,773,600	234,963
Catalytic	909,151	674,188	234,963

the national usage of each resource. A good quantity of these resources will ultimately be salvaged and recycled. There are expected to be no significant amounts of space (or land) required for the installation of control equipment and/or new coating technology, because all control systems can be located within little additional space. Therefore, the commitment of land on which to locate additional control devices and/or application equipment is expected to be minor.

As has been noted, the use of primary and secondary heat recovery would enhance the value of incineration. Without heat recovery, significant energy would be lost.

7.6.2 Environmental Impact of Delayed Standards

Delay of standards proposal for the automobile or light-duty truck industry will have negative environmental effects by increasing VOC emissions to the atmosphere and minor, or no, positive impacts on water and solid waste. Furthermore, there does not appear to be any emerging emission control technology on the horizon that could achieve greater emission reductions or result in lower costs than that represented by the emission control alternatives under consideration here. Consequently, delaying standards to allow further technical developments appears to present no trade-off of higher solvent emissions in the near future for lower emissions in the distant future.

7.6.3 Environmental Impact of No Standards

Growth projections have been presented in earlier sections. It is obvious that the increased production of automobiles and light-duty trucks will add to national solvent emissions.

There are essentially no adverse water and solid waste disposal impacts associated with the alternative emission control systems proposed in this section. Therefore, as in the case of delayed standards, there is no trade-off of potentially adverse impacts in these areas against the negative result on air quality which would be inherent with not setting standards.

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8. ECONOMIC IMPACT

Chapter 8 contains four sections covering the economic impact of the proposed VOC control. In Section 8.1, the structure of the motor vehicle industry and its role in the U.S. economy are described. Two major segments of the motor vehicle industry, passenger cars and light-duty trucks, are identified and characterized. This industry description includes geographic distribution, concentration and integration, import/export considerations, demand determinants, price determination, price leadership, price uniformity, nonprice considerations, price-cost relationships, projected demand, determination of existing capacity, and of projected capacity needs.

In Section 8.2, control costs and cost effectiveness for alternative VOC control systems are developed. Costs for controls of three variations of line speed for cars as well as for light-duty trucks are included.

Section 8.3 identifies other cost considerations and rates their potential impact on the economic analysis of emission control systems.

In Section 8.4, the economic impacts of alternative emission control systems are analyzed. Included is an assessment of the magnitude of cost of relative degrees of control and their impact on prices in the industry.

The major conclusion of Chapter 8 is that the economic impact of each considered alternative control system is moderately small and that the cost of NSPS should not preclude construction of new grass roots assembly lines.

8.1 INDUSTRY ECONOMIC PROFILE

8.1.1 Role of Motor Vehicle Industry in the U.S. Economy

The motor vehicle industry* occupies a key pivotal position in the U.S. economy. As a substantial consumer of steel, rubber, iron, aluminum, copper, zinc, lead, and glass, it determines to a certain extent the economic viability of these major U.S. manufacturing industries. In addition, the marketing and servicing of motor vehicles has created an infra-structure equally essential to other segments of the domestic economy, such as the petroleum industry.

About 2 percent of the gross national product and about 14 percent of the national income from durable goods are generated by the motor vehicle industry.[1] According to a recent report by a Federal task force, the industry provides direct employment for 955,000 members of the U.S. labor force. The magnitude of indirect employment is even more substantial; an additional 3.4 million Americans owe their livelihood, at least in part, to the existence of the motor vehicle.[2]

As a result of increased governmental requirements regarding environmental, safety, and fuel economy standards, the motor vehicle industry has entered a period of unprecedented technological change. Concommitantly, strong competition is present from the import sector of the market. The ability of the industry to cope with these and other exogenous constraints, such as changes in consumer taste, will determine whether the present role of the motor vehicle industry remains the same or is altered.

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*The term "motor vehicle industry" is used in this section to denote machine tool, parts and components, and assembly segments of the industry, regardless of vehicle type; in the following sections of this chapter the vehicle types considered are only passenger cars and light trucks, and the industry segments are broadened to include marketing and servicing.

8.1.2 Structure of the Industry

8.1.2.1 Concentration

The production of automobiles and light-duty trucks in the United States represents one of the nations's most concentrated industries. Three companies, General Motors, Ford Motor Company, and Chrysler Corporation, have accounted for most of the industry's production almost since its inception. The merger of two independents in 1954 resulted in the formation of American Motors Company, which subsequently became the fourth-ranking firm in the industry. Whether measured by capitalization, sales, profits, breadth of product line, or number of distribution outlets, General Motors is the dominant firm in the industry, followed by Ford, Chrysler, and American Motors, in that order.

Historically, many other firms have attempted to enter the market but U.S. based companies have not been successful in the long run. Checker Motors, International Harvester, and Volkswagen currently participate in the industry, but only on the periphery.

The automobile and light-duty truck industry is of such magnitude that it could conceivably accommodate a number of competitive firms in its structure. The fact that four firms have consistently comprised almost the entire industry suggests that they have acquired resources that have not only permitted them to survive, but have also forestalled the successful entry of other firms into the industry. However, a Canadian task force reviewing the North American automotive industry reached the conclusion that there is no evidence that there has been any attempt to limit competition despite the fact that it is virtually impossible for a new company to enter the motor vehicle market because of very high development and start-up costs.[3] The degree of vertical and horizontal integration present within the industry reflects the influence of these resources.

8.1.2.2 Integration

Vertical integration within the industry is obvious and well defined. Preproduction integration for some of the firms extends as far as captive iron and steel foundries, which provide the raw materials for component parts. Integration at the production level is largely achieved through captive establishments that supply many of the engines, transmission, fabricated parts, and other major components required for body and final assembly. Postproduct integration extends to franchised dealers who distribute the product and to subsidiary companies that finance consumer purchases. Postmarket integration exists in the form of franchised repair and supply facilities.

Horizontal integration is reflected in the firms' interests in the manufacture of nonautomotive products such as boats and farm equipment. International Harvester is the only significant company in light-duty truck manufacture that has a significant revenue from farm equipment.

8.1.2.3 The United States-Canada Automotive Agreement

The working relationship between the United States and Canada, beginning with implementation of the United States-Canada Automotive Products Agreement in 1965, established, in essence, a free trade zone between the two countries. It allowed the then-established U.S. automotive firms freedom of access to Canadian labor and consumer markets, and, through restrictive clauses in the Agreement, ensured the perpetuation of the Canadian automotive industry.* In effect, only General Motors, Ford, Chrysler, and American Motors are participants in the Agreement; Canada holds the right to impose tariffs on any other firms seeking to establish trade in the Canadian sector. To the extent that Canada chooses to exercise that right, Volkswagen's entry into the Canadian sector of the industry is constrained. The Agreement has no time limit, but either government may terminate it on 12 months notice. The net effect of the Agreement has been to provide an integrated North American motor vehicle industry and market. Consideration of the U.S. domestic motor vehicle industry in this study takes into account available Canadian resources and the reciprocal drain on U.S. production by Canadian demand.

8.1.2.4 Geographic Distribution

At the beginning of 1978, passenger cars and light-duty trucks** were being assembled at 51 and 31 locations, respectively, in the United States and Canada. Total reported outputs from these plants in 1977 were 10,095, 364 passenger cars and 3,455,504*** light-duty trucks.[4] A listing of North American passenger car assembly locations, by firm, is shown in Table 8-1 and light-duty truck locations, by firm, in Table 8-2.

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*The term "automotive industry" as used here includes both automobile and truck production.

**The term "light-duty truck" is defined in Chapter 3 of this report as "all vehicles with ratings of 8,500 pounds or less GVW." Included in this classification are pickup trucks, vans, panel trucks, station wagons built on pickup truck chassis, multistop trucks, and off-road vehicles.

***Lack of specificity in Canadian data required estimation of light-dutv truck production. This figure assumes light-duty truck production to be 90 percent of total truck production.

TABLE 8-1. NORTH AMERICAN AUTOMOBILE ASSEMBLY LOCATIONS[5]

1977

Manufacturer	Plant Location
General Motors Corporation	Arlington, Texas Baltimore, Maryland Detroit, Michigan Doraville, Georgia Fairfax, Kansas Flint, Michigan(2) Framingham, Massachusetts Fremont, California Janesville, Wisconsin Lakewood, Georgia Lansing, Michigan Leeds, Missouri Linden, New Jersey Lordstown, Ohio Norwood, Ohio Pontiac, Michigan South Gate, California St. Louis, Missouri N. Tarrytown, New York Van Nuys, California Willow Run, Michigan Wilmington, Delaware Oshawa, Ontario St. Therese, Quebec
Ford Motor Company	Atlanta, Georgia Chicago, Illinois Dearborn, Michigan Kansas City, Missouri Lorain, Ohio Los Angeles, California Louisville, Kentucky Mehwah, New Jersey Metuchen, New Jersey San Jose, California St. Louis, Missouri Twin Cities, Minnesota Wayne, Michigan Wixom, Michigan Oakville, Ontario St. Thomas, Ontario

TABLE 8-1. Concluded

Manufacturer	Plant Location
Chrysler Corporation	Belvedere, Illinois Hamtramck, Michigan Detroit, Michigan (2) Newark, Delaware St. Louis, Missouri Windsor, Ontario
American Motors Company	Kenosha, Wisconsin Brampton, Ontario
Checker Motors Company	Kalamazoo, Michigan

TABLE 8-2. NORTH AMERICAN LIGHT-DUTY TRUCK ASSEMBLY LOCATIONS[5]

1977

General Motors

Arlington, Texas
Baltimore, Maryland
Doraville, Georgia
Fremont, California
Janesville, Wisconsin
Lakewood, Georgia
Leeds, Missouri
Lordstown, Ohio
St. Louis, Missouri
Flint, Michigan
Oshawa, Ontario
Scarborough, Ontario

Ford

Atlanta, Georgia
Avon Lake, Ohio
Kansas City, Missouri
Lorain, Ohio
Louisville, Kentucky
Mahwah, New Jersey
Wayne, Michigan
San Jose, California
Norfolk, Virginia
Ontario Truck, Ontario
Oakville, Ontario

Chrysler

Warren, Michigan
Fenton, Michigan
Pilette Road, Ontario
Tecumseh Road, Ontario

American Motors

Toledo, Ohio
South Bend, Indiana*

International Harvester

Fort Wayne, Indiana

*This plant, operated by A.M. General Corp., a subsidiary of American Motors, is used for military and postal vehicle production.

Traditionally, production facilities have been centered in the Great Lakes region because of the availability of transportation for component parts to production facilities and for finished products from production facilities. However, differentials in labor costs and overhead have resulted in more recently built plants being located in nontraditional areas such as the southwestern part of the United States.

Recent industry growth continues to follow this pattern. Volkswagen, a newcomer to the domestic passenger car industry, began operations in New Stanton, Pennsylvania in March 1978. In Oklahoma, General Motors has begun construction of its first new car assembly plant in 14 years. This plant is scheduled to become operational for model-year 1980. Another plant being constructed by General Motors in Shrevesport, Louisiana, is expected to be producing light-duty trucks by 1981.

Extensive retooling of existing plants by several of the firms in the industry is planned in response to the need for compliance with energy, safety, and environmental standards set by the government.

8.1.2.5 Import/Export Considerations

8.1.2.5.1 Imports

Import penetration of the United States new car market began in earnest with the introduction of the Volkswagen Beetle in the late 1950's. By 1958 the economic climate resulting from the 1957 to 1958 recession, and a lack of small car production on the part of the domestic manufacturers, combined to make possible the capture of over 10 percent of the market by foreign imports.* This initial success was almost immediately offset, however, by a series of events that, for a time at least, returned the competitive edge to domestic manufacturers. One of these events was the introduction of competitively designed small cars into the domestic automobile lines. Another event was the recovery of the U.S. economy from the 1957 to 1958 recession, which brought with it an increased demand for larger, more expensive cars. The third event was the entry into the U.S. market of imports that proved unsatisfactory for American driving habits, and for American standards of maintenance and service. This resulted in a severe setback in the American public's confidence in, and acceptance of, foreign cars in general.

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*For purposes of this study, the term "foreign imports" is used to denote vehicles manufactured outside of North America.

Throughout the 1960's the trend in consumer purchases was toward large cars. Domestic manufacturers virtually abandoned the small-car concept. As a result, the share of the market for imports increased steadily. Japan's successful entry into the market in 1965 was a major milestone in import growth. Volkswagen sales had peaked by 1970, but Japanese imports continued to grow. Despite Detroit's attempt to fight back by introducing subcompacts such as the Pinto and Vega in 1971, and despite the devaluation of the dollar relative to Japanese and German currency after 1971, the trend in favor of imports continued. Market share for imports peaked at 18.2 percent in 1975, declined to 14.8 percent in 1976, and rose to 18.5 percent in 1977.

Imports have had a lesser impact on the light-duty truck market than on the new car market. In 5 of the last 8 years, the import share of the light-duty truck market has hovered between 8 percent and 9 percent, and it has not risen above 11.2 percent.[4,5] The inability of foreign manufacturers to penetrate the domestic market more extensively may be explained to some degree by restrictive tariffs that have been imposed on the importation of fully assembled light-duty trucks.

The degree of import penetration in the light-duty truck market becomes even less pronounced when the behavior of captive (foreign manufacture under domestic manufacturer contract) imports is considered. These have been commanding a larger share of the import market for several years. However, there is some doubt as to whether this trend will continue as the upcoming fuel economy standards for light-duty trucks raises the question of whether the required method of computing corporate mileage will include or exclude captive imports.

Recently, importers who have done well with light-duty trucks have begun exploring the possibility of making new breakthroughs in the heavy-duty truck market, based on an anticipated changeover from gas to diesel power. This poses a new threat to Ford and International Harvester, who are currently the leaders in heavy-duty truck production, and might well lead to their more aggressive participation in the light-duty truck market.[31]

The future of the import influence on the domestic market has two perspectives. Some analysts predict that the import share of the market will continue to rise because foreign manufacturers, reassured by continued positive sales performance, may consider establishing manufacturing operations in the U.S. This prediction would appear to be supported by the fact that in September 1977, Honda Motor Company of Japan revealed plans for the construction of a motorcycle plant in the United States, with car assembly the obvious next step.[5] The manufacturers of Toyota and Datsun, two leading Japanese imports, are also studying the possibility of establishing U.S. assembly facilities.

Critics of this viewpoint believe that the establishment of new facilities in the U.S. by foreign manufacturers need not imply further erosion of domestic market shares. They contend that the market share attributable to the new facility may come from the present share held by the same manufacturer. Some critics go even further and argue that import penetration is transient. The influence of government regulations regarding emission control, passenger safety, and fuel economy, and the narrowing of price competition between imports and domestic cars are seen as factors that will return a portion of the import market share to existing domestic manufacturers. In support of this contention, a review of the North American auto industry undertaken by the Canadian government in 1977 came to the conclusion that the tide of imports in the North American market "has peaked and the global industry has reached equilibrium."[6]

8.1.2.5.2 Exports

United States exports of finished cars to any country other than Canada are practically negligible. Not only have most other countries erected and maintained formidable trade barriers in this regard, but there is also little evidence that, even without these barriers, there would be any significant market there for United States cars. Therefore, U.S. car manufacturers have so far elected to put little emphasis on exports, per se, preferring instead to invest directly in car production plants, located within the countries themselves, for the production of European-type cars.[7] Exports are only a minor portion of U.S. truck sales, never having exceeded 100,000 units in any single year.[8]

8.1.2.6 Demand Determinants

Demand for new cars and light-duty trucks is a fluctuating phenomenon that reflects the influence of several classical determinants of demand. Consumer personal disposable income, consumer expectations, price, the availability of substitute goods, and consumer taste may all influence demand.

Income

The conclusion of most researchers has been that personal disposal income is the most important demand determinant.[9] When consumers are prosperous, car and light-duty truck sales tend to increase. When recession, inflation, high unemployment, and general economic uncertainty have been present, consumers have hesitated to purchase vehicles. A rise in car ownership by household tends to accompany a rise in real income. At high income levels, a saturation in the demand for additional automobiles is evident, with further income increases producing very little change in auto ownership.[10]

Expectations

Closely related to income is the consumer's expectations regarding the behavior of prices in relation to his anticipated income. Reflected in the increasing volume of car and light-duty truck sales is the expectation that prices will escalate more rapidly than personal income. To the extent that this is so, consumers tend to replace vehicles before anticipated price increases.

Price

Price also influences consumer demand for new vehicles. If price is increased, the quantity of cars or trucks demanded in the short run will fall as consumers postpone their purchase or turn to a substitute good.[11]

It should be noted that the demand for high-priced cars is less responsive to increased prices than is the demand for lower-priced cars.[12]

The consumer of the high-priced car will, as a general rule, postpone his purchase, but will not turn to a substitute good. However, consumers of lower-priced cars may downgrade their purchase[13] or may substitute a used car or a lower-priced import. Therefore, price differentials are extremely important in this area of the new car market. Price differentials are also extremely important in the light-duty truck market, since consumers can substitute either used or imported vehicles.

Substitute Goods

Viable substitutes for passenger cars and light-duty trucks include imported vehicles, used vehicles, and substitutions within and among model classes. Within certain settings, the accessibility of public transportation is also a factor. Imports and substitutions within and among model classes provide perfect substitutes for new vehicles. Used cars provide the consumer with a wide range of close substitutes. Public transit systems, taxicabs, rental vehicles, and commercial delivery services substitute only in metropolitan settings.

Taste

As a determinant of demand, consumer taste is most fickle, subjective, and nonquantifiable. Taste is comprised, among other things, of design, styling, size, brand loyalty, self-image, and status. Its influence is demonstrated by the recent trend away from the purchase of family cars and toward the purchase of vans and other light trucks for recreational use and leisure activities. It has been estimated that approximately 500,000 light-duty truck sales represent substitution sales for passenger cars in this past model year.[14]

8.1.2.7 Pricing Procedures

8.1.2.7.1 Price Determination

Pricing practices in the industry appear to substantiate the post-Keynesian economic theory that "the pricing behavior of oligopolistic firms in the manufacturing sector of industrialized capitalist economies can be explained by the demand for funds from internal sources for purposes of investment expenditures.[15] In theory, current actual costs are not used in pricing, and no attempt is made to maximize the rate of return in any single year. Demand is a factor in production rather than pricing, in that the immediate response to either increased or decreased demand is accelerated or decelerated production rather than higher or lower price. Thus, pricing to achieve a target rate of return is concerned with funding requirements for planned investment expenditures rather than current cost or demand conditions.

Over the years, General Motors has had the discretionary power to establish prices for its products that have generated sufficient cash flow to finance internally much of the investment expenditures it has undertaken. The pricing method used by General Motors is to project unit costs (direct labor and materials, plus unit overhead) on the basis of a "standard" volume (about 80 percent of capacity) and then add on a profit margin designed to yield a target rate of return sufficient to support long-range capacity and expansion objectives.[16]

Ford, Chrysler, and American Motors consider cost plus a reasonable profit as their base selling price. Ceiling prices have been set by pricing as close to the competition as possible.[17]

8.1.2.7.2 Price Leadership

The dominance of General Motors in the industry is evident in the 40 percent to 50 percent share of the domestic market it has held since 1931. This strong market share provides a basis for price leaderhip in the industry. While the role of first announcing price appears to be about equally divided between General Motors, Ford, and Chrysler, it is apparent that Ford and Chrysler frequently attempt to anticipate and follow the pricing actions of General Motors, and, when necessary, to backadjust.

A clear example of the latter type of movement occurred in September, 1956 when Ford announced a suggested price list for 1957 models that entailed an average 2.9 percent increase over 1956 models, ranging from $1 to $104 per model. Two weeks later, General Motors announced an average 6.1 percent increase over 1956 prices for its Chevrolet models, with price increases ranging from $50 to $166 per model. Within the week, Ford had revised its prices upward so that on ten models the price differential with Chevrolet was only $1 to $2. A week later, Chrysler announced the price of Plymouths at approximately $20 higher than Chevrolet, consistent with Chrysler's traditional pricing pattern.[18]

More recently, in response to the government's voluntary price deceleration program, General Motors announced that it would move away from the industry's usual practice of raising car prices once a year, and would, instead, raise prices whenever it was deemed appropriate.[19] In setting this new pricing trend, General Motors suggested that it would be able to keep price rises over the 1978 model year at about 5 to 5.5 percent compared with the 6 percent average boosts of the past 2 years. While neither Chrysler nor Ford has made any such commitment, a spokesman for Chrysler stated that "any pricing action in the future would continue to depend on the competitive situation and other factors."

8.1.2.7.3 Price Uniformity

Historically, list price differentials among different manufacturers' models in the same model class have tended to be small. Similarly, price differentials in the cost of accessories, options, and the hundreds of possible combinations of models/accessories are slight. The uniformity in pricing in these areas reflects the fact that General Motors has nearly half of the total market and twice the share of its nearest competitor, thereby effectively inundating price competition within the industry.

8.1.2.8 Nonprice Competition

In the North American automobile and light-duty truck market, much of the demand for vehicles is replacement demand. Because the purchase of a new vehicle is a deferrable item, and because perfect and close substitutes are available, manufacturers have had to develop strategies that ensure the constant stimulation of replacement sales. With the virtual disappearance of price differentials as a factor of competition, these strategies take the form of nonprice competition such as frequent design and styling changes, aggressive and imaginative marketing techniques, and dealer-buyer incentive programs.

Major design and styling changes are introduced by manufacturers every few years, with more modest changes in trim and styling occurring in the intervening years. To the extent that consumers see their vehicles as symbols of affluence, as a means of acquiring distinction, or as an expression of personality, these changes move them toward vehicle replacement.

Aggressive marketing techniques are evident in the public image each firm has established. Over the years, General Motors has maintained the strategy of advertising a "car for every price and purpose," and with its breadth of product line and range of options and accessories, it has managed to capture approximately 60 percent of the full-sized and intermediate-size car markets and to capture about 30 percent of the compact and subcompact market.

Ford's marketing strategy has been built on the concept of "basic transportation." Although Ford produces competitive models in all model classes, its greatest successes have been realized in the small car market. However, in recent years, Ford has elected to maintain a line of full-size and luxury cars as competitive alternatives to General Motor's downsizing of all its models. Ford's marketing strategy is apparently aimed at capturing that portion of the consumer market that elects to remain with a full-size car or that refuses to pay a full-size price for an intermediate-size car. Recently, Ford's share of the full-size market has ranged between 25 percent and 30 percent.

Chrysler's traditional marketing stance has been to build its image on superior engineering. While its products cover all model classes, Chrysler's historical appeal has been to the luxury and full-size car market. It has consistently priced its vehicles higher than those of its competitors, maintaining that they "are worth more, perform better, and have better engineering." In recent years, Chrysler's share of the full-size market has declined from 15 percent to about 10 percent, and last year, for the first time, Chrysler has moved into the domestic production of subcompacts with the introduction of the Omni and Horizon models.

American Motors historical strategy has been to produce less expensive economical, small cars. In the years in which the firm has departed from this strategy, sales have declined radically. Currently, American Motors has begun to concentrate its efforts in the compact and subcompact areas and to increase advertising of its Jeep products, which have consistently been successful.

Dealer-incentive programs include special sales campaigns that provide cash bonuses to dealers who exceed their sales quotas, special product promotions in which optional equipment is sold at reduced prices, and merchandise or trip prizes to outstanding salesmen or sales managers. Buyer-incentive programs include cash rebates on new vehicle purchases, special pricing on optional equipment, expansion of warranty items, and extensions of warranty periods.

8.1.2.9 Price-Cost Relationships

The price-cost margin, or profitability of sales, depends upon factors such as vehicle mix and the ability of the firm to recover cost increases. Because the industry is capital-intensive, fixed costs are high. Therefore, even a small change in unit volume will cause revenues to vary. As sales decline, the profit margin becomes narrower. Characteristically, the industry does not respond with a decrease in price in order to stimulate sales. To the extent that prices are held constant, increases or decreases in quantity of the product demanded will widen or narrow the profit margin.

In the 1972 to 1973 model year, sales in the industry peaked, and the profit position of the industry was maximized as the difference between costs and revenues widened. The subsequent decline in the market in response to the energy crisis produced by the Arab oil embargo did not result in a price decrease to induce greater sales volume. The industry practice of costing on a constant input basis, coupled with volume production, causes the implementation of price changes to take as long as 2 years. Therefore, the sales decline in 1974 to 1975 did not occasion a cutback, and the industry waited for the market to recover. As a result, that year was characterized by a substantial narrowing of the profit margin and reduced profitability.

It becomes apparent that the wider the profit margin of a manufacturer, the more flexibility he has in dealing with fluctuations in demand, changes in the costs of inputs, and in establishing prices. Conversely, smaller profit margins provide the manufacturers with less flexibility in these areas. Hence, profit margins become critical for companies that hold smaller shares of the market, such as American Motors and Chrysler Corporation. To the extent that prices must remain competitive, and because of the cost-revenue relationship, profitability for these companies becomes a matter of achieving a delicate balance. At the point where costs and revenues converge, or when costs exceed revenues, the long-run financial position of both companies will need to be such that long-run target profits can be met or external funds can be generated to finance capital expenditure demands of the company.

8.1.3 Projected Demand

Using current market shares and number of U.S. new car and light-duty truck registrations as the basis, United States demand for new cars and light-duty trucks was projected through 1983 for each individual firm.

For passenger cars, an annual industry growth of 3 percent was accepted as the "most likely" value from a range of estimated rates encountered in the course of research for this project. The upper limits of the range were 3.5 percent to 4 percent and the lower limits were 1.8 percent to 2 percent.[8,11] For trucks, an annual growth rate of 4 percent was accepted as the "most likely" value in a range of values from 3 percent to 6 percent suggested by authorities from both the public and private sectors of the economy.

Historical demand in Canada for new cars and for new light-duty trucks was examined in relation to historical demand in the United States. On the basis of the observed relationship, Canadian demand through 1983 was projected for the same time period as 10 percent of the United States demand for new cars, and 11 percent of United States demand for light-duty trucks.[2] Existing shares of the Canadian market were assumed to remain constant over the next 5 years for both cars and light-duty trucks.

United States demand and Canadian demand were combined to obtain total North American projected demand for new passenger cars (see Table 8-3) and for light-duty trucks (see Table 8-4).

8.1.4 Determination of Existing Capacity

In order to rationally determine the required new assembly lines needed for this industry, the existing capacity as well as future vehicle demand, was determined.

Estimates of existing production capacity for cars and for light-duty trucks were derived for each of the firms in the industry and are shown in Tables 8-5 and 8-6. For both cars and trucks, the basic formula used to measure production capacity for each firm was: (optimal line speed x number of final assembly lines) x (number of shifts x number of working days per year).

Optimal line speed is considered to be the optimal rate at which an automobile or truck assembly line can produce vehicles when the production

TABLE 8-3. U.S. AND CANADIAN PROJECTED DEMAND FOR NORTH-AMERICAN-MADE PASSENGER CARS[a], 1979 to 1983

(Thousands of Units)

Manufacturer[b]	1979	1980	1981	1982	1983
General Motors Corp.	5417	5580	5747	5919	6097
Ford Motor Co.	2653	2733	2815	2899	2986
Chrysler Corp.	1387	1428	1471	1515	1560
American Motors	206	212	218	225	232
Totals	9663	9953	10251	10558	10875

[a] Exports by U.S. manufacturers have not been included.

[b] Checker Motors, which produces for a specialized market, has a projected demand of 5576 units in 1983. Volkswagen's new car assembly plant in New Stanton, Pennsylvania, became operative in March 1978; sufficient sales data to project demand for 1983 are not yet available.

TABLE 8-4. PROJECTED U.S. AND CANADIAN DEMAND FOR NORTH-AMERICAN-MADE LIGHT-DUTY TRUCKS, 1979 to 1983

(Thousands of Units)

Manufacturer	1979	1980	1981	1982	1983
General Motors Corp.	1378	1422	1491	1550	1612
Ford Motor Company	1100	1144	1190	1238	1288
Chrysler Corporation	490	510	530	551	573
American Motors	116	121	126	131	136
Internat'l Harvester Company[a]	31	32	33	35	36
Totals	3115	3240	3370	3505	3645

[a] Estimates are for U.S. demand only.

TABLE 8-5. ESTIMATED PASSENGER CAR PRODUCTION CAPACITY IN NORTH AMERICA, 1978

Manufacturer	No. of Final Assembly Lines in U.S. and Canada	Estimated Capacity (Thousands of Units)
General Motors Corp.	29[a]	6,124
Ford Motor Co.	16	3,379
Chrysler Corp.	7[b]	1,478
American Motors Co.	2[b]	422
Checker Motors Corp.	1	211
Volkswagen of America, Inc.	1	211

[a] A new passenger car assembly plant in Oklahoma, presently under construction, is planned for 1980. Total capacity is estimated to increase by 211,200 units, bringing the total to 6,336,000 units.

[b] Allowance has been made in this table for the 1978 conversion to light-duty truck assembly of one line each for Chrysler and American Motors, and capacity estimates have been reduced accordingly.

TABLE 8-6. ESTIMATED LIGHT-DUTY TRUCK PRODUCTION CAPACITY IN NORTH AMERICA, 1978

Manufacturer	No. of Final Assembly Lines in U.S. and Canada	Estimated Capacity (Thousands of Units)
General Motors Corp.	11[a]	1,605
Ford Motor Co.	9	1,313
Chrysler Corp.	5[b]	729
American Motors Co.	3[c]	437
Internat'l Harverster Co.	1	145

[a] A new General Motors plant in Shrevesport, Louisiana has been planned for 1981. Estimated capacity should increased by 145,000 units, bringing the total to 1,750,000 units.

[b] Chrysler will cease light-duty truck production in its Tecumseh Road plant in 1979; this plant will be used for subassembly operations. The Jefferson Avenue plant converted in 1978 to light-duty truck production. It is assumed one change will offset the other.

[c] American Motors will retool its Brampton, Ontario plant in 1978 for light-duty truck production. The estimate presented here reflects this change.

rates of components and subassemblies are adjusted to be totally compatible. In accordance with the findings described in earlier chapters of this study, constant line speeds of 55 cars per hour and 38 trucks per hour were entered into the capacity formula. It is recognized that not every line in every company will operate at the accepted line speed; some will operate at a higher rate and others at a lower rate. Endogenous constraints such as the age of plants and equipment and the type and complexity of vehicle mix on a line are present. Also present are exogenous constraints such as the seasonal and cyclical nature of consumer demand. The accepted values represent best estimates of average car and truck optimal line speeds for the industry.

Number of lines per company is proprietary information. Data used for this component of the formula were estimated from public sources such as Ward's Automotive Yearbook and Automotive News, and the results were compared with other studies reporting similar information. Estimated number of lines per company reflects line usage for both automobile and light-duty truck production.

Number of shifts was established as a constant value of 2. It is understood that number of shifts may vary in response to consumer demand. This value was entered into the formula as representative of the industry.

Number of working days per year was established as a constant value of 240. This number is consistent with findings in earlier chapters of this study and reflects downtime required for maintenance, inventory, retooling for model changeover, vacation, and variations in labor skill.

8.1.5 Determination of New Sources

A company-by-company determination of new source requirements was made. Using the projected demand for 1979 and 1983, and considering factors as each company's market share, age and capacity of plants and publicized company plant changes or expansion, the following company line additions were concluded. General Motors will require an additional passenger car line by 1983 and one additional light-duty truck line by 1982; Ford will need one additional light-duty truck line by 1980; and Chrysler will need one additional passenger car line by 1980.

As demand at each firm exceeds present capacity, the firm may elect to build a new line. Alternatively, a firm may increase capacity by modifying or reconstructing an existing line. For example, Chrysler may choose to continue its announced program of gutting and refitting existing plants in order to increase production capacity to meet projected demand.[20] A second alternative for each firm would be to construct the new line in Canada, where environmental standards are currently somewhat less stringent.

The economic analysis in this study assumes that four new lines will be built, that they will be built in the United States and will be impacted by New Source Performance Standards.

8.2 COST ANALYSIS

8.2.1 Introduction

To determine the costs of controlling emissions of volatile organic compounds (VOC) associated with the painting of automobiles and light-duty trucks, alternative control systems were applied to selected typical plant sizes. Estimated costs were then plotted on graphs to represent the control option costs for varying plant capacities. The costs of the control options represent those additional expenditures over the base case, in which electrodeposition (EDP) is used for the prime coat, solvent-based coatings are used in the guide-coat and topcoat operations, and VOC emissions are not controlled. Figure 8-1 shows the available control options. The cost

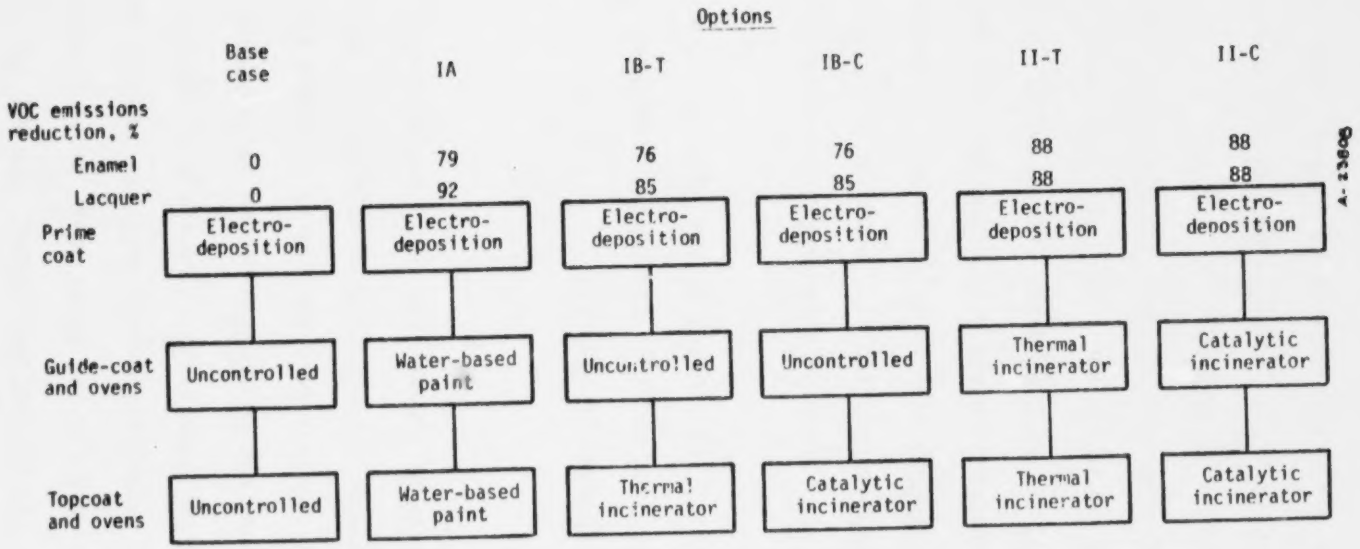
Options
Base case
IA
IB-T
IB-C
II-T
II-C
VOC emissions reduction, %
Enamel
0
79
76
76
88
88
Lacquer
0
92
85
85
88
88
Prime coat
Electro-deposition
Electro-deposition
Electro-deposition
Electro-deposition
Electro-deposition
Electro-deposition
Guide-coat and ovens
Uncontrolled
Water-based paint
Uncontrolled
Uncontrolled
Thermal incinerator
Catalytic incinerator
Topcoat and ovens
Uncontrolled
Water-based paint
Thermal incinerator
Catalytic incinerator
Thermal incinerator
Catalytic incinerator
A-23608

Figure 8-1. Available options for control of VOC emissions due to the painting of automobiles and light-duty trucks.

estimates developed herein are study estimates with an expected range of ±30 percent. They are limited to new coating facilities and are keyed to fourth quarter 1977 costs.

To represent the varying capacities of the assembly plants, three line speeds were selected from a range of actual industry production rates for automobiles and another three for light-duty trucks. For a given line speed, no cost distinction is made between automobiles and light-duty trucks. Any differences that may exist are too small to consider in a study estimate.

Vehicle Type	Line Speed, Vehicles/h
Automobile	40
	55
	85
Light-duty truck	30
	38
	48

It is assumed that vehicle manufacturers using solvent-based lacquers require three topcoat lines, those using solvent-based enamels require two topcoat lines, and those using water-based paints require two topcoat lines. For a given plant it is also assumed that all the topcoat lines are identical in length.

Realizing vehicle size directly affects potential VOC emissions, emission calculations are based on an average body size and paint thickness. Table 8-7 presents average solvent-borne paint usage for surface (guide) and topcoats.

Uncontrolled VOC emissions during guidecoat and topcoat application range from approximately 1.26 gigagrams/yr (1400 tons/yr) at an automobile assembly plant using enamel coatings and producing 40 vehicles/h to more than 6.35 gigagrams/yr (7000 tons/yr) at a plant using lacquer coatings and producing 85 vehicles/h. Using values from Table 8-7, an example of the enamel solvent calculations is as follows:

$$\begin{array}{cccccccccccc} \frac{\text{vehicles}}{\text{hour}} & \frac{\text{hours}}{\text{shift}} & \frac{\text{shift}}{\text{day}} & \frac{\text{liters guide}}{\text{vehicle}} & \cdot & \frac{\text{solvent}}{\text{content}} & + & \frac{\text{liters topcoat}}{\text{vehicle}} & \text{solvent content} & \frac{\text{gm solvent}}{\text{liter}} & \cdot & \frac{\text{day}}{\text{year}} \\ 40 & (8) & 2 & (2.0 & & (0.69) & + & 11.2 & (0.75)) & 839. & & (240) \end{array}$$

$$= 1.26 \times 10^9 \text{ gm/year}$$

8.2.2 Capital Cost of Control Options

The five control options incorporate two basic technologies: a change in coating material (from solvent-based to water-based paint) and incineration of the exhaust gases (by thermal or catalytic incineration).

8.2.2.1 Change to Waterborne Paint

Control option IA involves the use of water-based coatings. These coatings generally require longer spray booths, flash tunnels, and ovens than do solvent-based enamels, hence increased capital costs. The incremental increase of capital costs are less when water-based systems are compared with solvent-based lacquers, because a third (shroud) coat of lacquer is required for solvent spray systems. Table 8-8 lists the coating equipment requirements for the various types of coatings in a plant producing 55 vehicles/h.

The turnkey costs of booths, tunnels, and ovens are shown in Table 8-9. Costs include such items as air handling and conditioning, lighting, sprinklers, spray equipment, conveyors, and water-treatment

TABLE 8-7. AVERAGE SOLVENT-BASED PAINT USAGE FOR AUTOMOBILE AND LIGHT-DUTY TRUCK BODIES

Vehicle	Coating	Solvent Content, Percent by Volume	Paint Usage per Vehicle	
			Paint Usage per Vehicle, Liters	Gallons
Automobile	Enamel guide-coat	69	2.0	0.54
	Enamel topcoat	75	11.2	2.95
	Lacquer guide-coat	69	2.0	0.54
	Lacquer topcoat	87	25.3	6.67
Light-duty truck	Enamel guide-coat	69	2.0	0.54
	Enamel topcoat	72	12.2	3.23
	Lacquer guide-coat	69	2.0	0.54
	Lacquer topcoat	87	31.1	8.22

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TABLE 8-8. COATING EQUIPMENT REQUIREMENTS IN A PLANT PRODUCING 55 VEHICLES/HOUR[21]

Coating and Number of Lines	Equipment	Length Per Line, m (ft)
Water-based guide coat (1 line)	Spray booth	85 (280)
	Flash-off tunnel	85 (280)
	Oven	315 (1036)
Solvent-based guide coat (lacquer and enamel) (1 line)	Spray booth	67 (220)
	Flash-off tunnel	51 (168)
	Oven	315 (1036)
Water-based topcoat (2 lines)	Spray booth	94 (308)
	Flash-off tunnel	85 (280)
	Oven	128 (420)
Solvent-based enamel topcoat (2 lines)	Spray booth	30 (100)
	Flash-off tunnel	9 (30)
	Oven	76 (250)
Solvent-based lacquer topcoat (3 lines)	Spray booth	68 (224)
	Flash-off tunnel	51 (168)
	Oven	128 (420)

TABLE 8-9. TURNKEY COSTS OF AUTOMOBILE AND LIGHT-DUTY TRUCK COATING EQUIPMENT LINES

(4th quarter 1977 dollars)

Equipment	Estimated Cost	Cost Used in This Study
Water-based paint spray booth	36,000 - 39,000/m (11,000 - 12,000/ft)[a]	39,000/m (12,000/ft)
	39,000/m (12,000/ft)[b]	
Solvent-based paint spray booth	32,800/m (10,000/ft)[a,b]	32,800/m (10,000/ft)
Flash-off tunnels	32,800/m (10,000/ft)[a]	6,600/m (2,000/ft)
	6,600 - 7,800/m (2,000 - 3,000/ft)[b]	
Ovens	1,200 - 1,400/m^3 (35 - 40/ft^3)[a]	9,800/m (3,000/ft)
	6,600 - 9,800/m (2,000 - 3,000/ft)[b]	

[a] Reference 23
[b] Reference 24

equipment. In addition to the equipment costs, the land and building costs must be considered. Each unit is 6.1 m (20 ft) wide, and for purposes of estimating building costs, it is assumed that a 1.5 m (5 ft) aisle is required on each side of the booths, tunnels, and ovens. Ten percent was added for space between coating lines. A building cost of \$291.10/m^2 (\$26.20/ft^2) was used to calculate costs.[22] The real estate is assumed to cost \$24.80/m^2 (\$100,000/ac).

Table 8-10 presents the incremental capital costs of a water-based system versus conventional solvent-based systems for application of guide-coat and topcoat at plants of various line speeds. Calculation of these capital costs increments was accomplished by determining the additional line needed for water-based systems over solvent-based (unit line cost -- Table 8-9 -- x length -- Table 8-10 -- for water-based minus that for solvent-based) plus the additional land and building costs (additional line length needed times width (10.01 m) times land and building unit costs (291.10 + 24.80) \$/m^2). These costs are comparable to values presented in the literature.[27] The capital costs of similar systems are assumed to be directly proportional to line speed because the lengths of the spray booths, flash-off tunnels, and ovens are a function of line speed. A line speed that produces 70 vehicles per hour travels twice as fast as one which produces only 35 vehicles per hour. Thus, the ovens, for example, must be twice as long at the facility producing 70 vehicles per hour to achieve the same retention time.

8.2.2.2 Incineration

Control options IB and II require the use of thermal and catalytic incinerators. Capital costs were determined for incineration options based on a set of assumed operating parameters. These parameters include the

TABLE 8-10. INCREMENTAL CAPITAL COST INCREASES OF WATER-BASED GUIDE COAT AND TOPCOAT SYSTEM VERSUS CONVENTIONAL SOLVENT-BASED SYSTEMS

Type of Coating	Solvent-Based Enamel						Solvent-Based Lacquer					
Vehicles per hour	30	38	40	48	55	85	30	38	40	48	55	85
Capital Cost, $\$10^6$	5.65	7.15	7.53	9.05	10.2	16.0	0.39	0.50	0.52	0.63	0.72	1.11

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EXAMPLE CALCULATION FOR ADDED CAPITAL COSTS FOR 55 VEHICLES/HOUR ENAMEL COATING LINE.

Guide-Coat	L(M)C[a]	(\$/M)	-	L(M)C[a]	(\$/M)	
s.b.	85	(39,000)	-	67	(32,800)	
f.c.	85	(6,600)	-	51	(6,600)	
ov.	316	(9,800)	-	316	(9,800)	
	486	+		434 +		= 8.8 x 10^6 \$
Topcoat	L(M)C[a]	(\$/M)	-	L(M)C[a]	(\$/M)	
s.b.	2(94)	39,000	-	2(30)	32,800	
f.o.	2(85)	6,600	-	2(9)	6,600	
ov.	2(128)	9,800	-	2(76)	9,800	
	614			230		

Building/land 486 - 434 + 614 - 230 = 436 m length
(6.1 + 3.0) 1.1 = 10.01 m width A = 4362 m^2
(291.1 + 24.8) 4362 = 1.4 x 10^6 \$

10.2 x 10^6 \$

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[a] L(M)C is length of line in meters times the number of coats (1 or 2).

TABLE 8-11. TECHNICAL PARAMETERS USED IN DEVELOPING COSTS OF INCINERATORS FOR CONTROL SYSTEM[25]

Parameter	Value[a]	
1. Temperature, °C (°F)		
Ovens and flash tunnels	149	(300)
Spray booths	21	(70)
2. Volumetric flowrate, Nm^3/s (scfm) per vehicle/h		
Guide coat spray booth	0.645	(1,370)
Guide coat ovens and flash tunnels	0.087	(184)
Topcoat ovens and flash tunnels, enamel	3.82	(8,100)
Topcoat ovens and flash tunnels, enamel	0.105	(222)
Topcoat spray booth, lacquer	10.0	(21,200)
Topcoat ovens and flash tunnels, lacquer	0.273	(580)
3. Hydrocarbon concentration, % LEL[a]		
Spray booths	1.0	
Ovens and flash tunnels	10.0	
4. Control efficiency, %	90.0	

[a] LEL = lower explosive limit

following conditions and the values listed on Table 8-11. All exhaust gases are incinerated at 430°C (800°F) in the catalytic incinerators and 760°C (1400°F) in the thermal incinerators. Incinerators for oven and flash tunnel exhausts are designed for 35 percent primary and 55 percent secondary heat recovery. Only 35 percent primary heat recovery is considered for the spray booth exhausts.

The reactor units are shop-assembled packages complete with burners, fan, controls, heat exchanger, and stack. Maximum unit size is 23.5 Nm^3/s (50,000 scfm). If exhaust volumes exceed this rate, multiple units are used. Utility requirements are assumed to consist of electrical power to drive the fans and No. 2 fuel oil for the incinerator. Although natural gas would be used for catalytic incinerators, capital costs are uniformly developed for the more costly fuel of storage. Tanks with capacity for a 15-day fuel supply and ancillary facilities, such as dikes for above ground tanks, are included in the costs.

Direct capital cost items included in incinerator installation are foundations, rigging, structural steel, ductwork, dampers, electrical work, piping, temperature monitoring equipment, and painting. Indirect costs of system startup, performance testing, engineering, and the constructor's overhead and profit are also included. No allowance is made for stack monitors. However, since VOC emissions are a function of the temperature in the firing chamber, the cost of temperature monitoring equipment is included.

Because costs are estimated on a turnkey basis, cost of construction money is not specifically considered. Company philosophy and accounting methods have an impact on this. For purposes of this study, it is assumed that the cost of construction money is accounted for in the 25 percent allotted for the constructor's overhead and profit. The parameters used in developing the costs for incineration systems are shown in Table 8-11.

Table 8-12 presents delivered cost of incinerators from various exhaust flowrates. To determine installed costs, accessory equipment and installation charges were added to the delivered incinerator costs. Installation costs of the incinerators were estimated. Installed costs were then compared with the incinerator purchase prices. The ratio of estimated installed cost to purchase price ranged from 2.1 to 2.8. This

TABLE 8-12. DELIVERED COST OF EXHAUST GAS INCINERATORS[a] (1000 DOLLARS)

Incinerated Air Flowrate	Nm^3/s (scfm)					
Type of Incinerator	0.24 (500)	1.18 (2,500)	2.36 (5,000)	4.72 (10,000)	14.1 (30,000)	23.5 (50,000)
Ovens and flash tunnels 149°C (300°F) temperature 35% primary heat, recovery 55% secondary heat recovery						
Thermal units	75.5	85.0	105.0	122.0	176.0	226.0
Catalytic units	58.0	68.0	86.1	117.5	237.0	357.0
Spray booth exhaust 21°C (70°F) inlet temperature 35% primary heat recovery						
Thermal units	70.0	78.0	89.0	106.0	142.5	170.0
Catalytic units	53.0	60.0	70.0	97.5	203.5	301.0

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[a] Costs are based on those reported in Reference 26 and updated to 4th quarter 1977 prices. Freight is included.

compared favorably with previously reported ratios, which ranged from 1.2 to 3.7.[28] The estimated costs of dampers, oil storage, electric service, rigging, structural steel, foundations, ductwork, piping, painting, startup, and testing are based on engineering judgment. Installed costs include allowance of 25 percent for the constructor's overhead and profit and 12 percent for engineering. Tables 8-13 through 8-20 show the capital cost of each of the control options that incorporate exhaust gas incineration.

8.2.3 Annualized Cost of Control Options

The total annualized cost is divided into three categories: direct operating cost, capital cost, capital charges, and (when applicable) credit for heat recovery. Operating and maintenance costs fall into the first category and include the following:

- Utilities (including electric power, fuel, and process water)
- Operating labor
- Maintenance and supplies
- Solid waste disposal

Capital charges include depreciation, interest, administrative overhead, property taxes, and insurance. Depreciation and interest are computed by use of a capital recovery factor (CRF), the value of which depends on the operating life of the building or equipment and the interest rate. Table 8-21 lists the cost factors used in computing the annualized costs.

8.2.3.1 Water-based Paints

Water-based coating systems reportedly require more operating and maintenance labor than solvent-based coating systems.[27] Estimates of

TABLE 8-13. CAPITAL COSTS OF CONTROL OPTION IB-T FOR SURFACE COATING OF AUTOMOBILES (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	40	55	85	40	55	85
Emission Source						
Guide-coat spray booths	Unc.[a]	Unc.	Unc.	Unc.	Unc.	Unc.
Guide-coat flash tunnels and ovens	Unc.	Unc.	Unc.	Unc.	Unc.	Unc.
Topcoat spray booths	3,220	4,280	6,610	8,080	11,300	17,340
Topcoat flash tunnels and ovens	320	350	395	425	475	585
Total capital costs (rounded)	3,540	4,630	7,000	8,500	11,800	17,900

[a] Unc. -- Uncontrolled

TABLE 8-14. CAPITAL COSTS OF CONTROL OPTION IB-C FOR SURFACE COATING OF AUTOMOBILES (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	40	55	85	40	55	85
Emission Source						
Guide-coat spray booths	Unc.[a]	Unc.	Unc.	Unc.	Unc.	Unc.
Guide-coat flash tunnels and ovens	Unc.	Unc.	Unc.	Unc.	Unc.	Unc.
Topcoat spray booths	4,080	5,530	8,550	10,400	14,500	22,300
Topcoat flash tunnels and ovens	276	320	385	440	529	724
Total capital costs (rounded)	4,350	5,850	8,940	10,800	15,000	23,000

[a] Unc. -- Uncontrolled

TABLE 8-15. CAPITAL COSTS OF CONTROL OPTION II-T FOR SURFACE COATING OF AUTOMOBILES (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	40	55	85	40	55	85
Emission Source						
Guide-coat spray booths	745	835	1,260	745	835	1,260
Guide-coat flash tunnels and ovens	170	180	190	170	180	190
Topcoat spray booths	3,220	4,280	6,610	8,080	11,300	17,300
Topcoat flash tunnels and ovens	320	350	395	425	475	585
Total capital costs (rounded)	4,460	5,640	8,460	9,420	12,800	19,300

TABLE 8-16. CAPITAL COSTS OF CONTROL OPTION II-C FOR SURFACE COATING OF AUTOMOBILES (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	40	55	85	40	55	85
Emission Source						
Guide-coat spray booths	817	997	1,520	817	997	1,520
Guide-coat flash tunnels and ovens	142	150	162	142	150	162
Topcoat spray booths	4,080	5,530	8,550	10,400	14,500	22,300
Topcoat flash tunnels and ovens	276	320	385	440	529	724
Total capital costs (rounded)	5,320	7,000	10,620	11,800	16,200	24,700

TABLE 8-17. CAPITAL COSTS OF CONTROL OPTION IB-T FOR SURFACE COATING OF LIGHT-DUTY TRUCKS (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	30	38	48	30	38	48
Emission Source						
Guide-coat spray booths	Unc.[a]	Unc.	Unc.	Unc.	Unc.	Unc.
Guide-coat flash tunnels and ovens	Unc.	Unc.	Unc.	Unc.	Unc.	Unc.
Topcoat spray booths	2,620	3,610	4,080	7,420	8,740	12,100
Topcoat flash tunnels and ovens	292	320	345	413	485	562
Total capital costs (rounded)	2,910	3,930	4,420	7,830	9,220	12,700

[a] Unc. -- Uncontrolled

TABLE 8-18. CAPITAL COSTS OF CONTROL OPTION IB-C FOR SURFACE COATING OF LIGHT-DUTY TRUCKS (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	30	38	48	30	38	48
Emission Source						
Guide-coat spray booths	Unc.[a]	Unc.	Unc.	Unc.	Unc.	Unc.
Guide-coat flash tunnels and ovens	Unc.	Unc.	Unc.	Unc.	Unc.	Unc.
Topcoat spray booths	3,260	4,060	5,140	9,680	12,200	15,500
Topcoat flash tunnels and ovens	254	278	310	420	485	628
Total capital costs (rounded)	3,510	4,340	5,450	10,100	12,700	16,100

[a] Unc. -- Uncontrolled

TABLE 8-19. CAPITAL COSTS OF CONTROL OPTION II-T FOR SURFACE COATING OF LIGHT-DUTY TRUCKS (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	30	38	48	30	38	48
Emission Source						
Guide-coat spray booths	437	730	786	437	730	786
Guide-coat flash tunnels and ovens	172	172	172	172	172	172
Topcoat spray booths	2,620	3,610	4,080	7,420	8,740	12,100
Topcoat flash tunnels and ovens	292	320	345	413	485	562
Total capital costs (rounded)	3,520	4,830	5,380	8,440	10,100	13,600

TABLE 8-20. CAPITAL COSTS OF CONTROL OPTION II-C FOR SURFACE COATING OF LIGHT-DUTY TRUCKS (1000 DOLLARS)

Type of Coating Vehicles Per Hour	Solvent-Based Enamel			Solvent-Based Lacquer		
	30	38	48	30	38	48
Emission Source						
Guide-coat spray booths	537	790	907	537	790	907
Guide-coat flash tunnels and ovens	145	145	145	145	145	145
Topcoat spray booths	3,260	4,060	5,140	9,680	12,200	15,500
Topcoat flash tunnels and ovens	254	278	310	420	485	620
Total capital costs (rounded)	4,200	5,270	6,500	10,800	13,600	17,200

TABLE 8-21. COST FACTORS USED IN COMPUTING ANNUALIZED COSTS FOR CONTROL OPTIONS (1977 VALUES)

Operating factor	16 h/day 240 days/yr or 3840 h/yr
Maintenance labor rate	\$12.07/h
Operating labor rate	\$10.97/h
Supervisory labor rate	\$12.07/h
Utilities	
Electric power	\$0.0242/kWh
Fuel oil	\$0.107/liter (\$0.396/gal
Capital recovery factor[a]	
Air pollution control equipment (10 year life)	16.28% of capital cost control equipment
Production equipment (15 year life)	13.14% of capital cost production equipment
Buildings (20 year life)	11.02% of capital cost buildings
Taxes and insurance	2% of capital cost
Administrative overhead	2% of capital cost
Catalyst allowance	\$2120/yr per Nm^3/s (\$1.00/yr per scfm)

[a] 10 percent interest

additional labor needed for water-based guide and topcoats (in manhours per hour of line operation) are as follows:

	Lacquer	Enamel
Operating labor	10	20
Maintenance labor	7	7
Supervision	1	2

The cost of maintenance materials and supplies is assumed to be equal to the cost of maintenance labor.

Water-based painting facilities require considerably more energy than solvent-based coating facilities (see Table 7-9). Most of this additional energy is used to evaporate the water and condition the incoming air to the spray booths.

The cost of controlling water pollution associated with water-based coating facilities is estimated to be only slightly more than solvent-based coating facilities. Both systems use water cleanup for overspray. Water-based paints are believed to cost more than conventional coatings, but they also have a higher solids content. Although a comparison of paint prices was not available from the paint manufacturers or the automobile industry, the above would seem to indicate that the net applied paint cost is comparable for enamel and lacquer coatings and water-based coatings. General Motors uses water-based paint at two of its three California plants. Their response to an inquiry by the California Air Resources Board did not mention any net cost difference between water-based and solvent-based coatings.[27]

Figures 8-2 and 8-3 show annualized cost differentials between water-based coating operations and solvent-based operations at various

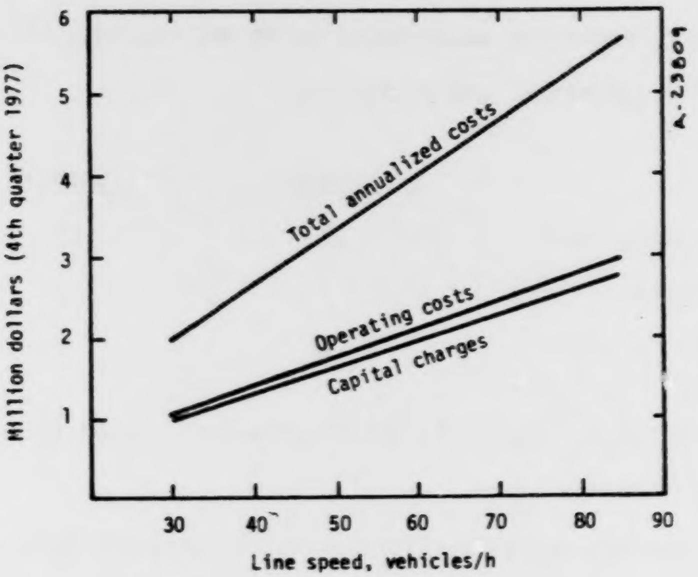

Figure 8-2. Cost differential -- control option IA for guide-coat and topcoat, water-based enamel vs. solvent-based enamel.

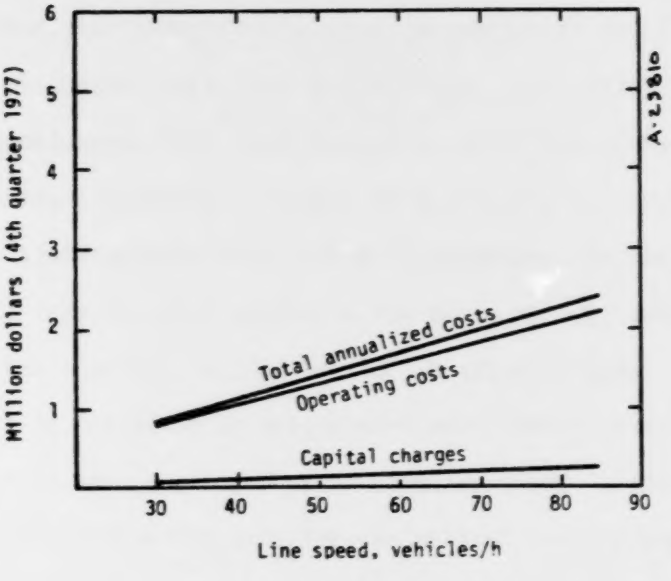

Figure 8-3. Cost differential -- control option IA for guide-coat and topcoat, water-based enamel vs. solvent-based lacquer.

line speeds. These annualized cost differentials were calculated as follows:

1. Additional production equipment costs were calculated (unit line cost -- Table 8-9 -- times length -- Table 8-10 -- for water-based minus solvent-based coating equipment)
2. Additional building costs were calculated (additional line length needed times width (10.01 m) times building unit costs (291.10 $\$/m^2$)
3. Both additional production equipment costs and additional building costs were then multiplied by their respective capital recovery factor, taxes, insurance, and administrative overhead factors (Table 8-21)
4. Additional labor costs were calculated (additional labor -- page 8-49 -- times labor rates -- Table 8-21). Additional maintenance material costs were assumed to be equivalent to the additional labor costs (page 8-49).
5. Additional utility costs were calculated (utility rates -- Table 8-21 -- times additional demand -- Table 7-9)

All of the above values were summed, yielding the total annualized cost differential as shown in Figures 8-2 and 8-3.

Tables 8-22 and 8-23 present annualized costs and cost-effectiveness of this control option for automobiles and light-duty trucks. Control efficiency percentages were determined from solvent emissions measured from water-based and organic solvent-based systems using a typical coating with air spray transfer efficiencies of 40 percent; application rates are given in Table 8-7. The computation of annualized costs is similar to that described above for Figures 8-2 and 8-3.

TABLE 8-22. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION IA FOR SURFACE COATING OF AUTOMOBILES

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $$10^6$			Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Total	
Enamel	40	1260 (1390)	79.0	995 (1098)	1.38	1.28	2.66	2670 (2422)
	55	1740 (1920)	79.0	1114 (1224)	1.80	1.75	3.64	3267 (3974)
	85	2700 (2970)	79.0	1714 (1888)	2.92	2.70	5.62	3279 (2976)
Lacquer	40	3010 (3310)	91.9	2780 (3060)	1.04	0.10	1.14	410 (372)
	55	4140 (4560)	91.9	3810 (4200)	1.42	0.13	1.55	407 (369)
	85	6390 (7040)	91.9	5880 (6480)	2.19	0.20	2.39	406 (370)

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TABLE 8-23. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION IA FOR SURFACE COATING OF LIGHT-DUTY TRUCKS

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $$10^6$			Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Total	
Enamel	30	990 (1090)	79.4	785 (865)	1.03	0.96	1.99	2540 (2300)
	38	1250 (1380)	79.4	1000 (1100)	1.31	1.21	2.52	2540 (2300)
	48	1580 (1740)	79.4	1250 (1380)	1.65	1.53	3.18	2540 (2300)
Lacquer	30	2750 (3030)	92.6	2550 (2810)	0.78	0.07	0.85	333 (302)
	38	3480 (3840	92.6	3230 (3560)	0.98	0.09	1.07	330 (300)
	48	4400 (4850)	92.6	4080 (4500)	1.24	0.11	1.35	330 (300)

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The two differences are: (1) cost differentials are replaced by control option costs, and (2) capitol costs now involve air pollution control equipment -- not production equipment and building costs.

8.2.3.2 Incineration

Cost factors used to compute the annualized costs of controlling VOC emissions from the guide-coat and topcoat operations are shown in Table 8-21. Operating labor for each incinerator, regardless of size, includes 1.0 manhour for each startup and shutdown and 0.25 manhour per shift for monitoring. Each incineration unit must be tuned up and the heat exchangers must be cleaned twice yearly, as regular maintenance which together with miscellaneous maintenance, requires an estimated 64 manhours per year per incinerator. Operating and maintenance labor is calculated as being independent of incinerator size.

It is estimated that the catalyst in catalytic incinerators must be replaced yearly at a cost of $\$2120/\mathrm{Nm}^3$ per second (\$1.00/scfm).

Because total exhaust rates differ between solvent-based lacquer and solvent-based enamel operations, the annualized costs also vary; control of emissions from solvent-based lacquer is more costly.

Heat recovered by the primary heat recovery systems with the incinerators on spray booths is used to preheat the spray booth exhausts. The resultant saving is not considered a credit from a cost standpoint; rather it is accounted for in the decreased fuel rate. On the other hand, the heat obtained from secondary heat recovery can be considered credit because it is used for production facilities, mainly oven heating. All the incinerators used on oven exhausts have primary and secondary heat recovery. The heat recovered in the secondary heat exchanger is credited at the rate of \$2.68 gigajoules ($\$2.83/10^6$ Btu).

Tables 8-24 through 8-31 present the annualized costs of the four incinerator control options for automobiles and light-duty trucks. Annual costs are determined for control option IB and II using the factors in Tables 8-13 through 8-21. Calculations are the same as for option IA except air pollution control equipment is the additional capital expense rather than production lines.

8.2.4 Cost-Effectiveness of the Control Options

In this section a comparison of the annualized costs of the various alternative control options to the quantities of VOC removed by them, or a cost-effectiveness analysis, is made on each of the control options and each of the model coating facilities.

The purpose of this comparison is to determine (1) which is the most practical control option, (2) whether the options differ in cost-effectiveness, and (3) whether the expenditure of additional monies can be justified by the amount of pollutant controlled.

Tables 8-22 and 8-23 list these cost-effectiveness quotients for control option IA. It is clear from these tables that the quotients are virtually identical for automobiles and light-duty trucks when compared with the base case of solvent-based enamels, but there is a spread of approximately 20 percent between the two when compared with the base case of solvent-based lacquers. This spread results from the higher lacquer requirements for truck bodies; when lacquer is used, a light-duty truck requires about 23 percent more topcoating than an automobile, but when enamel is used, the difference is only about 5 percent.

There is a large difference in the cost-effectiveness of water-based coatings compared with enamels and water-based coatings compared with lacquers because water-based coatings need less spray booth, flash-

TABLE 8-24. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION IB-T FOR SURFACE COATING OF AUTOMOBILES

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $$10^6$				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	40	1260 (1390)	77	970 (1070)	3.43	0.73	(0.05)	4.11	4240 (3840)
	55	1740 (1920)	77	1340 (1480)	4.84	0.95	(0.07)	5.62	4200 (3800)
	85	2700 (2970)	77	2080 (2280)	7.27	1.45	(0.11)	8.61	4150 (3780)
Lacquer	40	3010 (3310)	85	2560 (2820)	8.94	1.75	(0.14)	10.6	4140 (3760)
	55	4140 (4560)	85	3520 (3880)	12.30	2.42	(0.18)	14.5	4120 (3740)
	85	6390 (7040)	85	5420 (5980)	19.00	3.69	(0.28)	22.4	4130 (3750)

[a]Rounded

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TABLE 8-25. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION IB-C FOR SURFACE COATING OF AUTOMOBILES

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $$10^6$				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	40	1260 (1390)	77	970 (1070)	2.18	0.89	(0.03)	3.04	3130 (2840)
	55	1740 (1920)	77	1340 (1480)	3.00	1.19	(0.04)	4.15	3100 (2800)
	85	2700 (2970)	77	2080 (2300)	4.61	1.81	(0.06)	6.36	3060 (2770)
Lacquer	40	3010 (3310)	85	2560 (2800)	5.67	2.22	(0.07)	7.82	3060 (2790)
	55	4140 (4560)	85	3520 (3880)	7.78	3.05	(0.10)	10.7	3040 (2760)
	85	6390 (7040)	85	5430 (5980)	12.0	4.69	(0.16)	16.5	3040 (2760)

[a] Rounded

EE-25R

TABLE 8-26. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION II-T FOR SURFACE COATING OF AUTOMOBILES

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $10^6				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	40	1260 (1390)	90	1130 (1250)	4.02	0.91	(0.06)	4.87	4310 (3900)
	55	1740 (1920)	90	1570 (1730)	5.53	1.16	(0.08)	6.61	4210 (3830)
	85	2700 (2970)	90	2430 (2670)	8.49	1.75	(0.12)	10.1	4160 (3780)
Lacquer	40	3010 (3310)	90	2710 (2980)	9.52	1.94	(0.14)	11.3	4170 (3800)
	55	4140 (4560)	90	3730 (4100)	13.1	2.62	(0.19)	15.5	4160 (3780)
	85	6390 (7040)	90	5750 (6340)	20.2	3.99	(0.30)	23.9	4160 (3780)

[a] Rounded

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TABLE 8-27. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION II-C FOR SURFACE COATING OF AUTOMOBILES

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $10^6				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	40	1260 (1390)	90	1130 (1250)	2.56	1.08	(0.03)	3.61	3200 (2900)
	55	1740 (1920)	90	1570 (1730)	3.51	1.42	(0.04)	4.89	3120 (2820)
	85	2700 (2970)	90	2430 (2670)	5.39	2.16	(0.07)	7.48	3080 (2800)
Lacquer	40	3010 (3310)	90	2710 (2980)	6.05	2.41	(0.08)	8.38	3100 (2810)
	55	4140 (4560)	90	3730 (4100)	8.29	3.28	(0.10)	11.5	3080 (2800)
	85	6390 (7040)	90	5750 (6340)	12.8	5.03	(0.16)	17.7	3080 (2800)

[a] Rounded

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TABLE 8-28. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION IB-T FOR SURFACE COATING OF LIGHT-DUTY TRUCKS

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $10^6				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	30	990 (1090)	78	770 (850)	2.70	0.60	(0.04)	3.26	4220 (3840)
	38	1250 (1380)	78	975 (1080)	3.42	0.73	(0.05)	4.10	4200 (3820)
	48	1580 (1740)	78	1230 (1360)	4.34	0.90	(0.07)	5.17	4200 (3820)
Lacquer	30	2750 (3030)	85	2340 (2580)	8.28	1.62	(0.12)	9.78	4180 (3800)
	38	3480 (3840)	85	2960 (3260)	10.4	2.03	(0.16)	12.3	4160 (3770)
	48	4400 (4850)	85	3740 (4120)	13.2	2.55	(0.20)	15.6	4170 (3780)

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[a] Rounded

TABLE 8-29. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION IB-C FOR SURFACE COATING OF LIGHT-DUTY TRUCKS

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $\$10^6$				Cost-Effectiveness, \$/Mg VOC Removed (\$/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	30	990 (1090)	78	770 (850)	1.72	0.72	(0.02)	2.42	3140 (2850)
	38	1250 (1380)	78	975 (1080)	2.17	0.89	(0.02)	3.04	3110 (2820)
	48	1580 (1740)	78	1230 (1360)	2.75	1.11	(0.04)	3.82	3100 (2820)
Lacquer	30	2750 (3030)	85	2340 (2580)	5.25	2.06	(0.07)	7.24	3100 (2820)
	38	3480 (3840)	85	2960 (3260)	6.64	2.59	(0.09)	9.14	3090 (2800)
	48	4400 (4850)	85	3740 (4120)	8.39	3.29	(0.11)	11.6	3100 (2820)

[a] Rounded

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TABLE 8-30. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION II-T FOR SURFACE COATING OF LIGHT-DUTY TRUCKS

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $10^6				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	30	990 (1090)	90	890 (980)	3.15	0.72	(0.04)	3.83	4290 (3900)
	38	1250 (1380)	90	1120 (1240)	3.98	0.91	(0.06)	4.83	4300 (3900)
	48	1580 (1740)	90	1420 (1570)	5.04	1.10	(0.07)	6.07	4280 (3870)
Lacquer	30	2750 (3030)	90	2480 (2730)	8.72	1.75	(0.13)	10.3	4150 (3770)
	38	3480 (3840)	90	3130 (3460)	11.0	2.21	(0.16)	13.1	4180 (3790)
	48	4400 (4850)	90	3960 (4360)	13.9	2.74	(0.20)	16.4	4140 (3760)

[a] Rounded

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TABLE 8-31. INCREMENTAL ANNUALIZED COSTS OF CONTROL OPTION II-C FOR SURFACE COATING OF LIGHT-DUTY TRUCKS

Type of Conventional Coating with Which Option Is Compared	Line Speed, Vehicles/h	Uncontrolled VOC Emissions, Mg/yr (tons/yr)	Control Efficiency, Percent	VOC Emission Reduction, Mg/yr (tons/yr)	Annualized Cost, $10⁶				Cost-Effectiveness, $/Mg VOC Removed ($/ton VOC Removed)
					Direct Operating	Capital Charges	Secondary Heat Recovery Credit	Total[a]	
Enamel	30	990 (1090)	90	890 (980)	2.0	0.85	(0.03)	2.82	3170 (2880)
	38	1250 (1380)	90	1120 (1240)	2.53	1.08	(0.03)	3.58	3200 (2890)
	48	1580 (1740)	90	1420 (1570)	3.20	1.33	(0.04)	4.49	3160 (2860)
Lacquer	30	2750 (3030)	90	2480 (2730)	5.53	2.20	(0.07)	7.66	3090 (2810)
	38	3480 (3840)	90	3130 (3460)	7.0	2.78	(0.09)	9.69	3100 (2800)
	48	4400 (4850)	90	3960 (4360)	8.84	3.50	(0.11)	12.2	3080 (2800)

[a] Rounded

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off tunnel, and oven facilities than do solvent-based lacquer coatings, whereas they need more of these facilities than do solvent-based enamels.

The VOC emitted by coating operations using solvent-based lacquers are more than twice those emitted by operations using solvent-based enamels. This results partly from the higher solvent content of lacquers and partly from the additional paint required for each vehicle. On the other hand, lacquers require greater volumes of dilution air. Although emissions generated from lacquers cost more to control than those from enamels, more VOC is removed and the cost-effectiveness remains about the same for a given control option using incinerators.

Figures 8-4 and 8-5 compare the cost-effectiveness of each of the control options. Control option IA, the use of water-based paint, is the most cost-effective option in all cases.

As the cost-effectiveness lines indicate, no economy-of-scale occurs in controlling the larger facilities because these facilities require proportionately higher exhaust gas rates and the maximum-sized incinerator is 23.5 Nm^3/s (50,000 scfm), thus necessitating more incinerators. Thus, gas incineration costs are proportional to plant capacity. Neither does control option IA (a switch to water-based paint) exhibit an economy-of-scale for basically the same reason; more pieces of the same size equipment are required in larger facilities. Finally, for all control options, the operating costs are larger than the capital charges. The nature of these costs is such that they are directly proportional to production rate, which also militates against economics-of-scale.

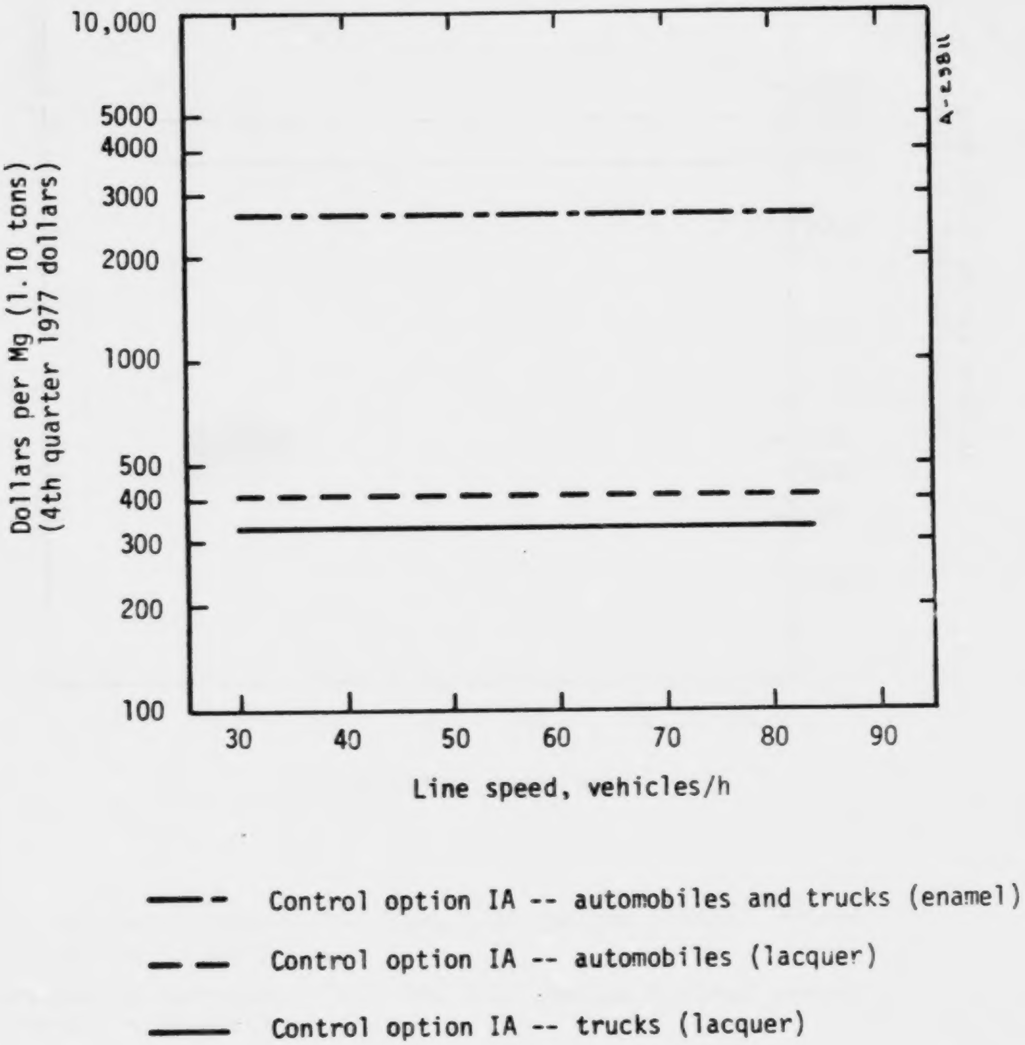

Figure 8-4. Cost-effectiveness of water-based control options.

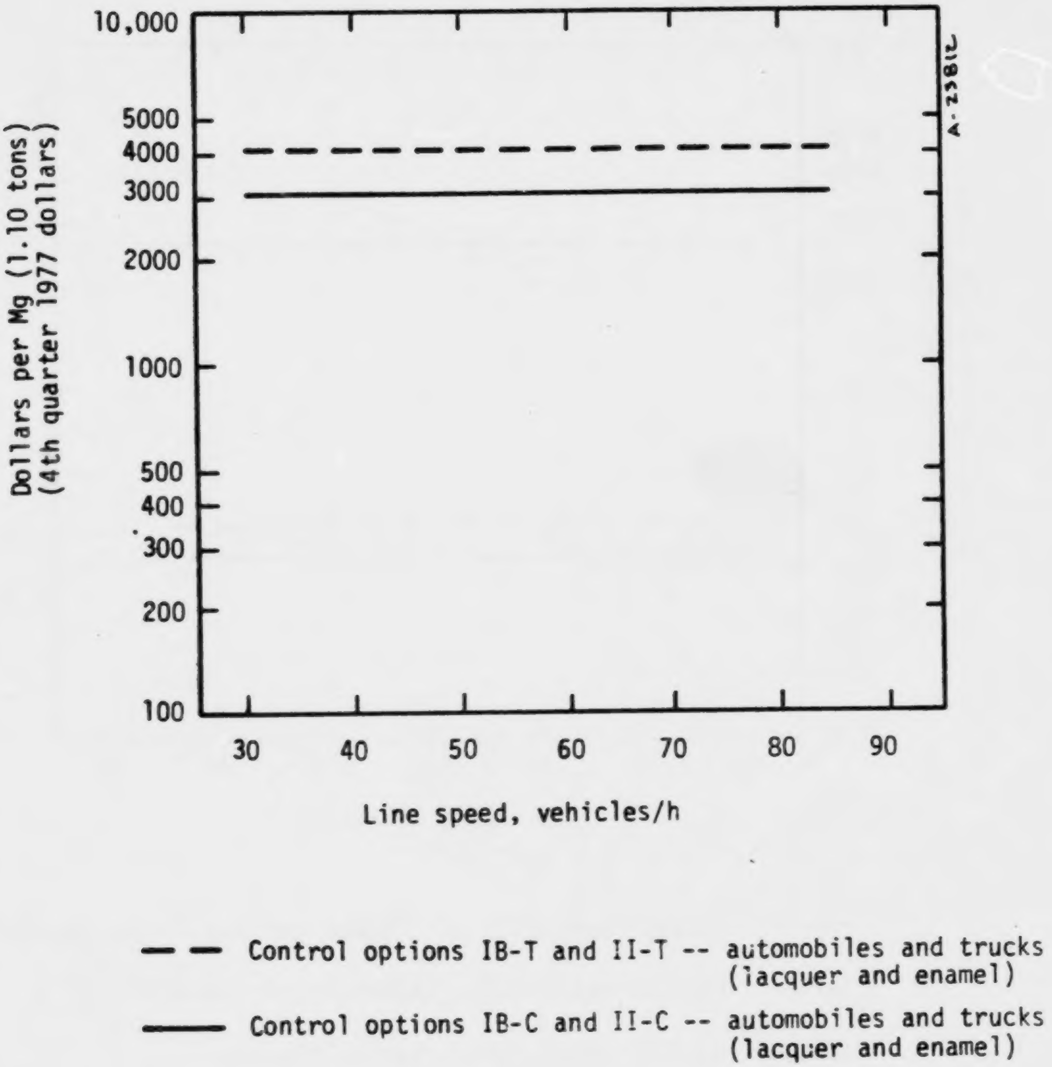

Figure 8-5. Cost-effectiveness of incineration control options.

The cost-effectiveness of each of the control options may be summarized as follows:

Option	Cost-Effectiveness, $/Mg VOC controlled
IA	330-410 (lacquer-base case) 2500-3300 (enamel-base case)
IB-T	4200
IB-C	3100
II-T	4200
II-C	3100

8.2.5 Control Cost Comparison

It is difficult to compare the estimated cost of water-based coating operations with costs reported at actual installations. For example, cost data presented to the California Air Resources Board by two of the major automobile manufacturers[27] cannot be compared directly with the estimated costs of water-based operations presented in this report because the figures are aggregated, they include many items not included in control option IA, and they are based on a "tear-out/redo" premise. After their detailed review, the values were considered to be on the high side by the staff of the Air Resources Board. The turnkey costs of spray booths, flash-off tunnels, and ovens for water-based paint were provided by vendors, however, and the quoted prices are substantially lower than the industry retrofit estimate given to the California Air Resources Board. Because no direct cost data for new line installations could be extracted from the California report or from other industry sources, the vendor's turnkey prices were used.

Much of the increase in annualized coating costs is due to increased energy consumption when using water-based paints. In this case some comparison can be made with the data that GM supplied to the California Air Resources Board. The actual recorded incremental increase at the Van Nuys plant (which has a production rate of 60 vehicles/h) was 89.4 TJ/yr (84.8 x 10^9 Btu/yr). The study estimate for control option IA at a plant producing 55 vehicles/h includes an incremental increase of 76.5 TJ/yr (72.4 x 10^9 Btu/yr) for additional fuel oil and 44.6 TJ/yr (42.3 x 10^9 Btu/yr) for additional electricity.

Incinerator costs used in this study are based on a 1976 report[26] and updated to fourth quarter 1977 prices. These prices compare reasonably well with older installations as reported in a 1972 report.[28] The prices shown in the 1972 report were also updated to fourth quarter 1977. Figures 8-6, 8-7 and 8-8 compare costs used in this study with costs in other studies.[28,29]

8.2.6 Base Cost of the Facility

For purposes of comparison, a base cost of solvent-based painting facilities has been developed under this study. This base cost includes the complete cost of an electrodeposition (EDP) prime coating facility, a guide-coat facility, a topcoat facility, and touch-up facilities. The cost of related support facilities such as employee parking, material storage, and a cafeteria is also included.

Because this is a study estimate, costs are not detailed. It is assumed that the costs of painting facilities for automobiles and light-duty trucks are basically the same for both. For study purposes, it is assumed that base costs are proportional to line speed. The base cost of a paint shop that uses lacquer is higher than the cost of one that uses enamel. Total costs were estimated for a facility that handles 55 vehicles per hour.

Building space was estimated at 17,500 m^2 (188,000 ft^2) for lacquer facilities and 11,800 m^2 (127,000 ft^2) for enamel facilities.

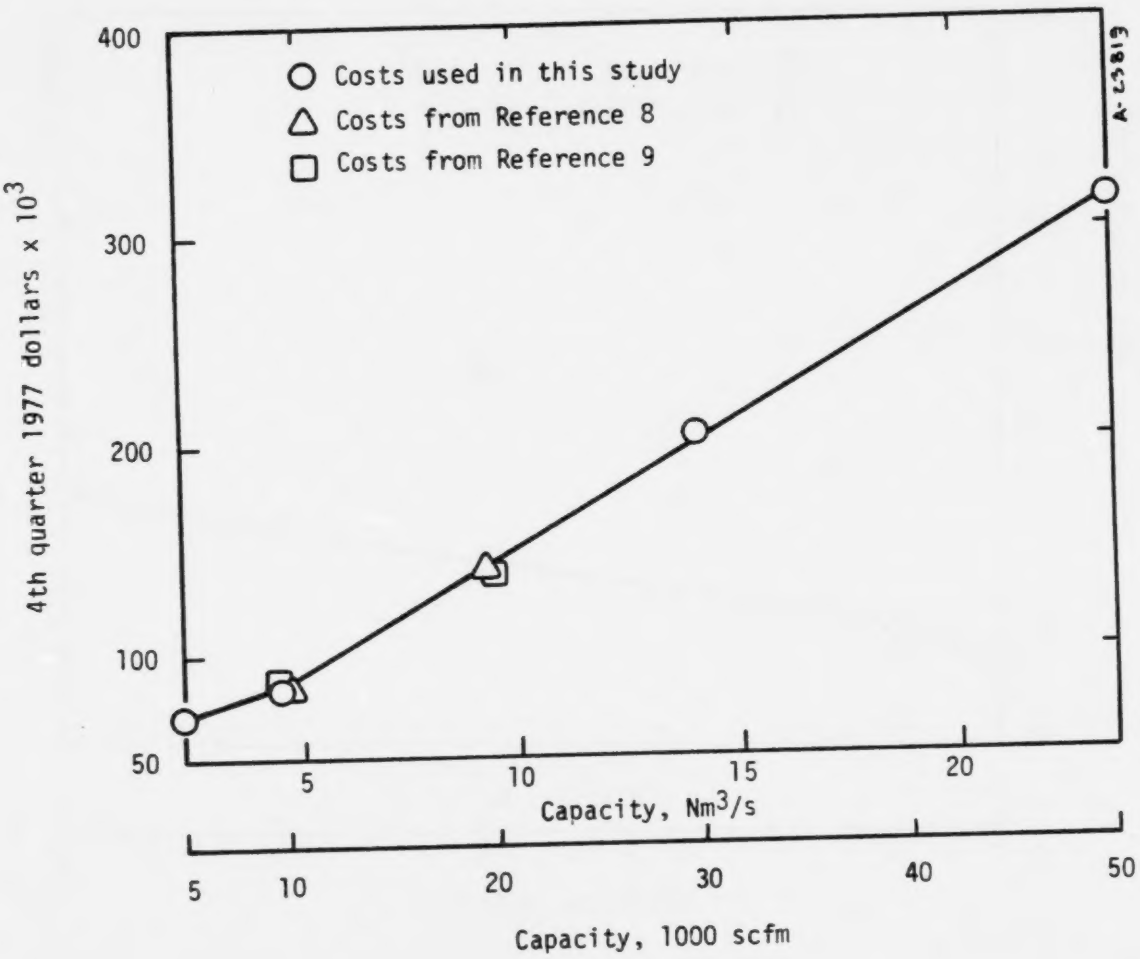

Figure 8-6. Comparison of purchase price values: catalytic incinerators with primary heat recovery.

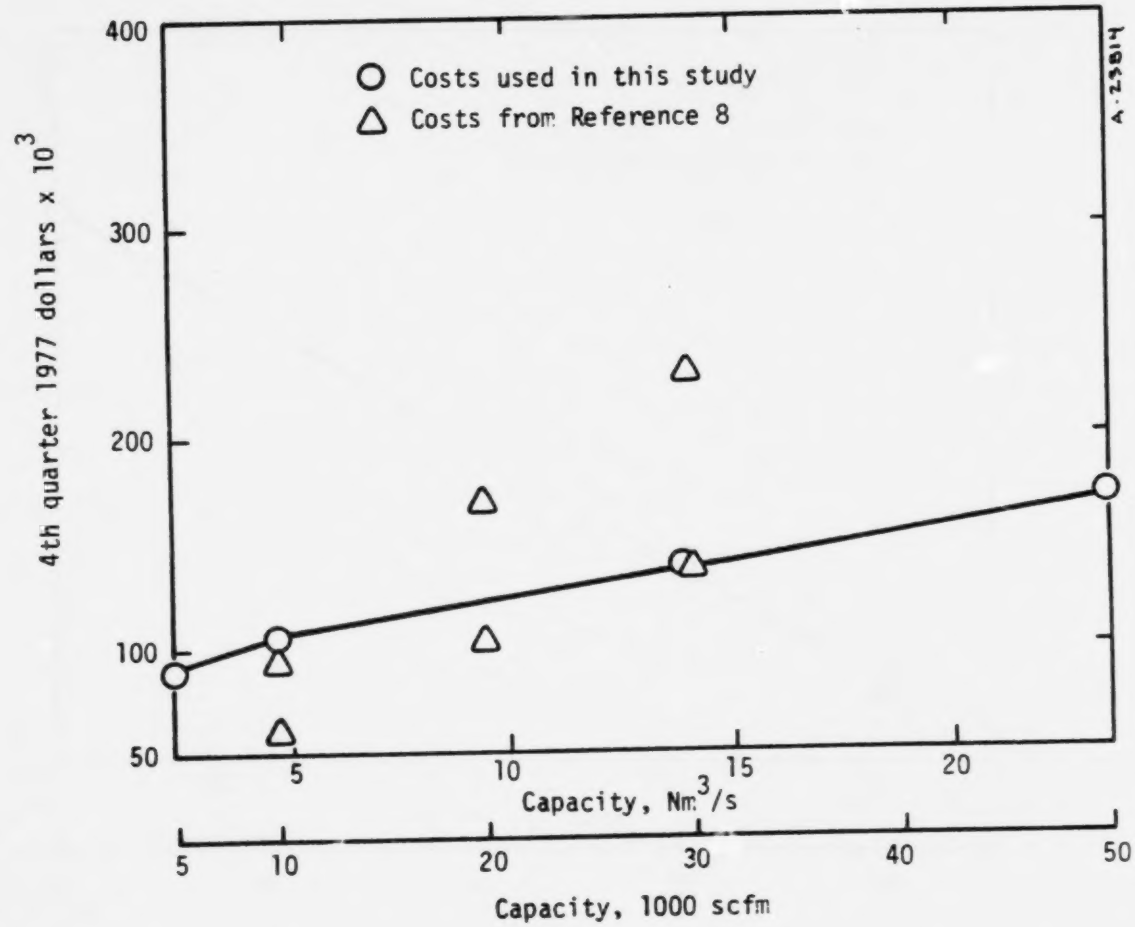

Figure 8-7. Comparison of purchase price values: thermal incinerators with primary heat recovery.

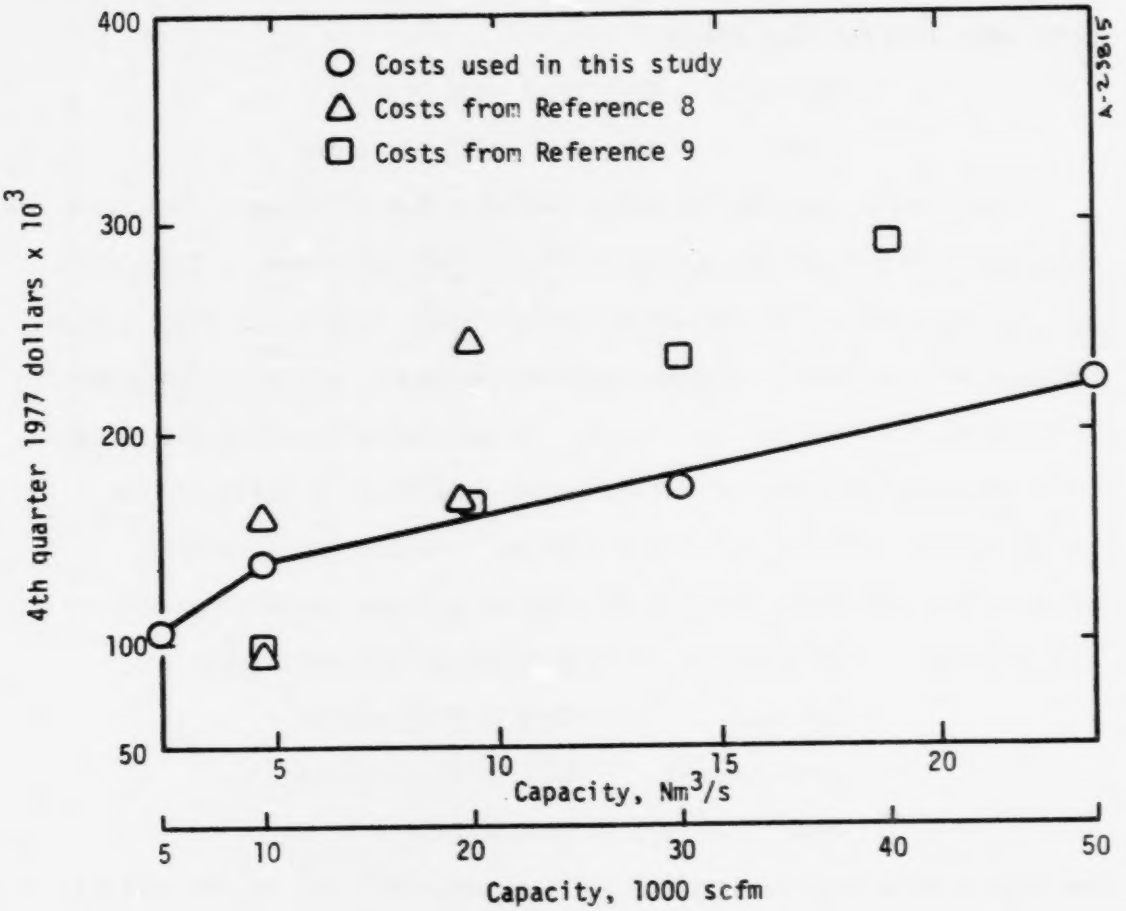

Figure 8-8. Comparison of purchase price values: thermal incinerators with primary and secondary heat recovery.

These figures include 3250 m^2 (35,000 ft^2) for EDP in both instances. In addition, 835 m^2 (9,000 ft^2) of building space for employee services (e.g., cafeteria and dispensary) and employee parking facilities for 300 vehicles is included in the base cost estimate. This figure is based on 500 employees working two shifts. The following unit costs were used for real estate:

Buildings -- \$291.10/m^2 (\$26.20/ft^2)
Land -- \$24.80/m^2 (\$100,000/acre)

Unit costs used for the spray booths, flash-off tunnels, and ovens are shown in Table 8-9 and the aggregate line lengths are shown in Table 8-32.

Electrodeposition facilities include rinse tunnels, an oven, and an EDP tank with ancillary equipment such as conveyors, electrical equipment, ventilation, and hooding. An industry representative reported that recent costs of retrofitted EDP facilities ranged from \$11.4 to \$14.8 million, and an average facility cost \$12.6 million. One vendor's turnkey estimate for a facility handling 55 vehicles per hour ranged from \$6.5 to \$9.5 million. The following is a breakdown of this estimate:

EDP tank	\$2.0 to \$3.5 million
Rinse tunnels	\$1.5 to \$2.0 million
Oven	\$3.0 to \$4.0 million

The high side of this range (\$9.5 million) compares with the retrofitted average of \$12.6 million and was used in preparing this estimate. Tables 8-33 and 8-34 present total base cost for various line speeds.

TABLE 8-32. AGGREGATE LENGTHS OF SPRAY BOOTHS, FLASH-OFF TUNNELS, AND OVENS FOR PAINT SHOPS HANDLING 55 VEHICLES PER HOUR[a]

(m (ft))

Facility	Type of Solvent-Based Paints	
	Lacquer	Enamel
Spray booths	292 (956)	147 (484)
Flash-off tunnels	235 (772)[b]	100 (238)[b]
Ovens	735 (2408)	502 (1648)

[a] Based on three topcoat lines for lacquer coatings and two topcoat lines for enamel coatings.
[b] Includes 7.3 m (24 ft) of cooling area.

TABLE 8-33. BASE COST OF AN AUTOMOBILE AND LIGHT-DUTY TRUCK PAINT SHOP THAT USES SOLVENT-BASED ENAMEL

	Installed Costs, $\$10^6$					
Line Speed, Vehicles/h	30	38	40	48	55	85
Guide, top, and touch-up coating facilities[a]	7.2	9.1	9.6	11.5	13.2	20.4
EDP facility[a]	5.7	7.3	7.6	9.2	10.5	16.2
Ancillary facilities[a]	0.3	0.4	0.4	0.5	0.6	0.9
Totals	13.2	16.8	17.6	21.2	24.3	37.5

[a] Includes cost of land and building

TABLE 8-34. BASE COST OF AN AUTOMOBILE AND LIGHT-DUTY TRUCK PAINT SHOP THAT USES SOLVENT-BASED LACQUER

	Installed Costs, $\$10^6$					
Line Speed, Vehicles/h	30	38	40	48	55	85
Guide, top, and touch-up coating facilities[a]	12.5	15.8	16.6	19.9	22.8	35.1
EDP facility[a]	5.7	7.3	7.6	9.2	10.5	16.2
Ancillary facilities[a]	0.3	0.4	0.4	0.5	0.6	0.9
Totals	18.5	23.5	24.6	30.6	33.9	52.2

[a] Includes cost of land and building

8.3 OTHER COST CONSIDERATIONS

In addition to NSPS, the automotive industry will be impacted by other mobile source emission control, safety, fuel economy, and noise-control regulations. However, the imposition of these other regulations probably will not affect the results of the analysis contained in Section 8.4 since they will impact vehicle unit size and construction rather than numbers.

A comprehensive study to evaluate the combined economic impact of all government regulations on the automotive industry is presently being conducted by A. T. Kearney, Inc. Results are not available at this time.

8.4 POTENTIAL ECONOMIC IMPACT

The impact of the standards of performance based on all options proposed are computed in this section as the annualized cost per unit of production for each company effected. The projected economic impact of each considered alternative control option on the required grass roots new lines is small, and the cost of compliance with Standards of Performance for New Source should not, by itself, preclude the construction of any of these lines.

8.4.1 Grass Roots New Lines

As determined in Section 4.1.5 projected new source requirements are to include: one car and one truck line for General Motors, one truck line for Ford, one car line for Chrysler, and no new lines for American Motors, Checker, and International Harvester.

8.4.2 Control Costs

The absolute and relative magnitude of the estimated alternative control costs for grass roots new lines, by firm, are shown in Tables 8-35 through 8-38. In all cases, the estimated incremental control costs are

TABLE 8-35. ABSOLUTE AND RELATIVE INCREMENTAL CONTROL COSTS, NEW SOURCE:
PASSENGER CAR -- GENERAL MOTORS CASE
(Dollars -- 4th Quarter 1977)

Line Speed/Cost Category	Alternatives				
	1A	1B-T	1B-C	11-T	11-C
40 cars/hour					
Annualized cost per line	$1,140,000	$10,600,000	$ 7,820,000	$11,000,000	$ 8,380,000
Annualized cost/car[a]	$.18	$1.64	$1.21	$1.70	$1.30
Annualized cost/unit cost[b]	.01%	.05%	.04%	.06%	.04%
Capital cost of control alternative	$ 520,000	$ 8,500,000	$10,900,000	$ 9,470,000	$11,800,000
Capital cost as % of company plan	.02%	.25%	.32%	.28%	.35%
55 cars/hour					
Annualized cost per line	$1,550,000	$14,500,000	$10,700,000	$15,500,000	$11,500,000
Annualized cost/car[a]	$.24	$2.24	$1.66	$2.40	$1.78
Annualized cost/unit cost[b]	.01%	.07%	.05%	.08%	.06%
Capital cost of control alternative	$ 720,000	$11,800,000	$15,000,000	$12,800,000	$16,200,000
Capital cost as % of company plan	.02%	.35%	.44%	.38%	.48%
85 cars/hour					
Annualized cost per line	$2,390,000	$22,400,000	$16,500,000	$23,900,000	$17,700,000
Annualized cost/car[a]	$.37	$3.47	$2.55	$3.70	$2.74
Annualized cost/unit cost[b]	.01%	.11%	.08%	.12%	.09%
Capital cost of control alternative	$1,110,000	$17,900,000	$23,000,000	$19,300,000	$24,700,000
Capital cost as % of company plan[c]	.03%	.53%	.68%	.57%	.73%

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[a] 6,464,000 passenger cars for 1982

[b] *3074 suggested retail

[c] Planned capital expenditures for the year in which the new plant is expected to be completed

TABLE 8-36. ABSOLUTE AND RELATIVE INCREMENTAL CONTROL COSTS, NEW SOURCE: LIGHT-DUTY TRUCKS -- GENERAL MOTORS CASE
(Dollars -- 4th Quarter 1977)

Line Speed/Cost Category	Alternatives				
	1A	1B-T	1B-C	11-T	11-C
30 cars/hour					
Annualized cost per line	$ 850,000	$ 9,780,000	$ 7,240,000	$10,340,000	$ 7,660,000
Annualized cost/car[a]	$.47	$5.38	$3.98	$5.68	$4.21
Annualized cost/unit cost[b]	.01%	.13%	.09%	.13%	.10%
Capital cost of control alternative	$ 390,000	$ 7,830,000	$10,100,000	$ 8,440,000	$10,800,000
Capital cost as % of company plan	.01%	.23%	.30%	.25%	.32%
38 cars/hour					
Annualized cost per line	$1,070,000	$12,300,000	$ 9,140,000	$13,100,000	$ 9,690,000
Annualized cost/car[a]	$.59	$6.76	$5.02	$7.20	$5.33
Annualized cost/unit cost[b]	.01%	.16%	.12%	.17%	.13%
Capital cost of control alternative	$ 500,000	$ 9,220,000	$12,700,000	$10,100,000	$13,600,000
Capital cost as % of company plan	.02%	.27%	.37%	.30%	.40%
48 cars/hour					
Annualized cost per line	$1,350,000	$15,600,000	$11,600,000	$16,400,000	$12,230,000
Annualized cost/car[a]	$.74	$8.58	$6.38	$9.02	$6.72
Annualized cost/unit cost[b]	.02%	.20%	.15%	.21%	.16%
Capital cost of control alternative	$ 630,000	$12,700,000	$16,100,000	$13,600,000	$17,200,000
Capital cost as % of company plan[c]	.02%	.37%	.47%	.40%	.51%

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[a] 1,819,000 passenger cars for 1982

[b] *4233 suggested retail

[c] Planned capital expenditures for the year in which the new plant is expected to be completed

TABLE 8-37. ABSOLUTE AND RELATIVE INCREMENTAL CONTROL COSTS, NEW SOURCE: LIGHT-DUTY TRUCKS -- FORD CASE

(Dollars -- 4th Quarter 1977)

Line Speed/Cost Category	Alternatives				
	1A	1B-T	1B-C	11-T	11-C
30 cars/hour					
Annualized cost per line	$1,990,000	$ 3,260,000	$ 2,420,000	$ 3,830,000	$ 2,830,000
Annualized cost/car[a]	$1.49	$2.45	$1.82	$2.87	$2.12
Annualized cost/unit cost[b]	.04%	.06%	.04%	.07%	.05%
Capital cost of control alternative	$5,650,000	$ 2,910,000	$ 3,510,000	$ 3,520,000	$ 4,200,000
Capital cost as % of company plan	.24%	.12%	.15%	.15%	.18%
38 cars/hour					
Annualized cost per line	$2,520,000	$ 4,100,000	$ 3,030,000	$ 4,830,000	$ 3,580,000
Annualized cost/car[a]	$1.89	$3.08	$2.27	$3.62	$2.69
Annualized cost/unit cost[b]	.04%	.07%	.05%	.09%	.06%
Capital cost of control alternative	$7,150,000	$ 3,930,000	$ 4,340,000	$ 4,830,000	$ 5,270,000
Capital cost as % of company plan	.30%	.16%	.18%	.20%	.22%
48 cars/hour					
Annualized cost per line	$3,180,000	$ 5,180,000	$ 3,820,000	$ 6,070,000	$ 4,490,000
Annualized cost/car[a]	$2.39	$3.89	$2.87	$4.55	$3.37
Annualized cost/unit cost[b]	.06%	.09%	.07%	.11%	.08%
Capital cost of control alternative	$9,050,000	$ 4,420,000	$ 5,450,000	$ 5,380,000	$ 6,500,000
Capital cost as % of company plan[c]	.38%	.18%	.23%	.22%	.27%

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[a] 1,333,000 passenger cars for 1982
[b] *4221 suggested retail
[c] Planned capital expenditures for the year in which the new plant is expected to be completed

TABLE 8-38. ABSOLUTE AND RELATIVE INCREMENTAL CONTROL COSTS, NEW SOURCE: PASSENGER CAR -- CHRYSLER CASE

(Dollars -- 4th Quarter 1977)

Line Speed/Cost Category	Alternatives				
	1A	1B-T	1B-C	11-T	11-C
40 cars/hour					
Annualized cost per line	$2,660,000	$ 4,110,000	$ 3,040,000	$ 4,880,000	$ 3,610,000
Annualized cost/car[a]	$1.76	$2.71	$2.01	$3.22	$2.38
Annualized cost/unit cost[b]	.05%	.07%	.05%	.09%	.06%
Capital cost of control alternative	$7,530,000	$ 3,540,000	$ 4,350,000	$ 4,460,000	$ 5,314,000
Capital cost as % of company plan	1.0%	.5%	.6%	.6%	.7%
55 cars/hour					
Annualized cost per line	$ 3,640,000	$ 5,620,000	$ 4,150,000	$ 6,610,000	$ 4,890,000
Annualized cost/car[a]	$2.40	$3.71	$2.74	$4.36	$3.23
Annualized cost/unit cost[b]	.06%	.1%	.07%	.12%	.09%
Capital cost of control alternative	$10,300,000	$ 4,630,000	$ 5,850,000	$ 5,640,000	$ 7,000,000
Capital cost as % of company plan	1.3%	.6%	.8%	.7%	.9%
85 cars/hour					
Annualized cost per line	$ 5,620,000	$ 8,610,000	$ 6,360,000	$10,100,000	$ 7,480,000
Annualized cost/car[a]	$3.71	$5.68	$4.20	$6.67	$4.94
Annualized cost/unit cost[b]	.1%	.2%	.1%	.2%	.1%
Capital cost of control alternative	$16,000,000	$ 7,000,000	$ 8,940,000	$ 8,460,000	$10,620,000
Capital cost as % of company plan[c]	2.1%	.9%	1.1%	1.1%	1.4%

EE-270

[a] 1,515,000 passenger cars for 1980

[b] *3706 suggested retail

[c] Planned capital expenditures for the year in which the new plant is expected to be completed

less that a quarter of one percent of the list price for each manufacturer's lowest-priced automobile or light-duty truck. The capital investment costs of the alternative control options are also exceedingly small in relation to the planned annual capital expenditures of each firm.

For the incremental cost calculations, annualized costs for each company's line were spread over the year's production volume. This was judged consistent with the industry's pricing policy. The April 1978 published list price, as reported in Automotive News, was deemed acceptable as a base price for comparison purposes. It was assumed that the additional price of optional equipment would offset any price discount by the dealer.

For General Motors, the annualized costs of a new line are, at most, $3.70 per passenger car and $9.02 per light-duty truck.* These annualized costs are, respectively, 0.1 percent of General Motors suggested list price for its lowest-priced passenger car and 0.2 percent of the suggested list price for its lowest-priced, light-duty truck. The capital investment required for controlling both lines, assuming that the highest annualized cost option was adopted by General Motors, is slightly less than 1 percent of the firm's planned annual capital expenditures for 1982.

For Ford, the annualized cost per truck is $4.55 at most. This is 0.1 percent of the suggested list price for Ford's lowest-priced, light-duty truck. The corresponding capital investment requirement, if Ford selected this control option and line speed, is less than 0.3 percent of Ford's planned annual capital expenditures for 1980.

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*The methodology used to derive each manufacturer's annualized costs on a per unit basis, in keeping with traditional industry pricing practices, assumes that the incremental costs attributable to the New Source Performance Standard will be distributed by the manufacturer over all units sold rather than over the production volume of the new line.

For Chrysler, annualized costs per passenger car would be, at most, $6.67, which amounts to 0.2 percent of Chrylser's suggested list price for its lowest-priced car. Should Chrysler choose this option, 1.1 percent of its planned capital expenditures for 1980 would be needed for this purpose.

If cost figures were distributed only for the vehicles coated on the new lines, annualized costs per vehicle would increase from a least cost base of $0.18/car to $7.43/car for General Motors auto line to a highest cost base of $9.02/truck to $89.06/truck for their light-duty truck line.

As is evident in Tables 8-35 through 8-38, control costs for each manufacturer tend to become higher as line speeds increase. This is due to the increased number of vehicles that are affected and are, therefore, a greater percent of the manufacturer's output.

8.4.3 Potential Price Effect

Several factors must be considered in analyzing potential price increases attributable to Performance Standards for New Source. For one thing, not every manufacturer will incur NSPS-related cost increases in the same year by reason of new assembly line construction. Both Chrysler and Ford will probably incur such costs earlier than General Motors. On the other hand, all firms in the industry, including those not impacted by 1983, will eventually effect NSPS-related cost increases.

Another point to be considered is that it will probably not be possible to determine which portion of the firm's price increase in any given year is reflecting NSPS-related costs since, as a rule, current prices to not reflect current cost in the automotive industry.

Annual price increases for new cars have averaged approximately 5 percent over the past 5 years and 4.38 percent over the past 10 years. The magnitude of volatile organic compound emission control cost increases, is, at most, a 0.1 percent per car and 0.2 percent per light-duty truck for General Motors. For Ford, the cost increase is 0.1 percent per light-duty truck and for Chrysler, 0.2 percent per car. Since these price changes are based on the lowest-priced vehicle for each manufacturer, the percentage change should become almost infinitesimal when compared with the range of vehicle prices for each manufacturer. It is apparent that the relative magnitude of these projected NSPS-related cost increases to historical average price increases is small. Independently, they should not cause significant cost-price increases for cars or light-duty trucks through 1983.

The ability of Ford and Chrysler to adjust their revenue functions so as to effect an NSPS-related price change will depend upon the pricing behavior of General Motors, the industry price leader. Ford and Chrysler can adjust their revenue functions only within the constraints imposed by the degree, timing and nature of price changes announced by General Motors.

A consideration of Ford's desired price increase relative to that of General Motors suggests that there should be no adverse effects on Ford's profitability function regardless of ths size, timing, or nature of the change. The effect of Chrysler's revenue function is less predictable. Critical to Chrysler's ability to adjust its revenue function is the nature and magnitude of General Motors desired price change. If future price changes by General Motors are not of the nature and magnitude to allow Chrysler to pass along the entire NSPS increase, then Chrysler's profitability function will probably by somewhat adversely affected.

Recently, General Motors announced a new price increase strategy that would permit small price increases to take place over a model year, as frequently as the firm deems necessary. By eliminating the traditional annual increase in favor of the new system, manufacturers would appear to be recovering cost increases more quickly. While General Motors pricing strategy imposes constraints on the ability of other members of the industry to recover costs, the new pricing strategy may provide some relief in cost recovery. It is also possible that the system will "flatten out" a degree of the cyclical nature of sales. In effect, consumer purchasing patterns may become more consistent throughout the year and less negatively influenced by one large annual increase. To the extent that sales volume increases consistently over the year, cost recovery may take place rapidly enough to permit lower total annual increases while maintaining target rates of return.

8.4.4 Sensitivity Analysis

The economic impact that has been projected in this chapter assumes that market shares of each company will remain constant through 1983. To give recognition to the possibility that these shares could shift, a sensitivity analysis, based on the assumption that each company had regained the highest market share it had held in the past 5 years, was conducted. This scenario calculation indicated that, were these market shares possible: General Motors would need one truck line; Ford would need one car line and one additional truck line; Chrysler would need two additional car lines and a truck line; and American Motors would need a car line.

It should be noted in this context that it is obviously impossible for all companies to achieve their top market shares simultaneously. In any case, the annualized costs involved would still be minimal with 0.7 percent increase for cars and 0.2 percent increase for trucks being the largest single unit price increase.

The sensitivity test did not indicate any restructuring of relative positions within the industry. There were indications, however, that if market shares for Chrysler and/or American Motors increased appreciably in the passenger car market, there could be a resultant adverse effect on their profit margins, since these firms would be producing more units with associated NSPS cost increases and would still be in the position of being constrained in passing along those costs by whatever pricing action was being taken by General Motors. However, the probability that either firm will be able to recapture a substantially higher market share is remote.

8.5 POTENTIAL SOCIOECONOMIC AND INFLATIONARY IMPACTS

Since the major potential impact of these regulations, that of preventing plant expansion of new coating lines, is not considered probable, the impact will be determined by company response to reduced production margins. Output and employment effects should be minimal. Secondary response of added demand on energy prices will be upward but of an insignificant amount.

As a longer term inflationary seed, the maximum cost increase due to these regulations should be less than 1 percent of the anticipated unit price. This determination was developed by computing the total investment costs to achieve compliance by 1983. Table 8-39 shows the projected amount of fifth year annualized costs including depreciation and interest. The estimated $57 million dollars is less than $4.90 per vehicle industry wide or $79 per new line vehicle. Increased costs of this magnitude are not considered as a significant inflationary force.

TABLE 8-39. INFLATIONARY IMPACT ASSESSMENT 1983[a]
(4th Quarter 1977 $)

Manufacturer	No. of Lines	Fifth-Year Annualized Costs (1000's)	Investment Costs (1000's)	No. of Vehicles Impacted (1000's)
General Motors Corp.	2	$40,300	$32,900	8,366
Ford Motor Co.	1	$ 6,070	$ 5,380	1,521
Chrysler Corp.	1	$10,100	$ 8,460	1,657
Total	4	$56,470	$46,740	11,544

[a] Based on Regulatory Option II (thermal)

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9. RATIONALE

9.1 SELECTION OF SOURCE AND POLLUTANTS

Volatile organic compounds (VOC) are organic compounds which participate in atmospheric photochemical reactions or are measured by Reference Methods 24 (Candidate 1 or Candidate 2) and 25. There has been some confusion in the past with the use of the term "hydrocarbons." In addition to being used in the most literal sense, the term "hydrocarbons" has been used to refer collectively to all organic chemicals. Some organics which are photochemical oxidant precursors are not hydrocarbons (in the strictest definition) and are not always used as solvents. For purposes of this discussion, organic compounds include all compounds of carbon except carbonates, metallic carbides, carbon monoxide, carbon dioxide and carbonic acid.

Ozone and other photochemical oxidants result in a variety of adverse impacts on health and welfare, including impaired respiratory function, eye irritation, deterioration of materials such as rubber, and necrosis of plant tissue. Further information on these effects can be found in the April 1978 EPA document "Air Quality Criteria for Ozone and Other Photochemical Oxidants," EPA-600/8-78-004. This document can be obtained from the EPA library (see ADDRESSES Section).

Industrial coating operations are a major source of air pollution emissions of VOC. Most coatings contain organic solvents which evaporate upon drying of the coating, resulting in the emission of VOC. Among the largest individual operations producing VOC emissions in the industrial coating category are automobile and light-duty truck surface coating operations. Since the surface coating operations for automobiles and light-duty trucks are very similar in nature, with line speed being the primary difference, they are being considered together in this study. Automobile and light-duty truck manufacturers employ a variety of surface coatings, most often enamels and lacquers, to produce the protective and decorative finishes of their product. These coatings normally use an organic solvent base, which is released upon drying.

The "Priority List for New Source Performance Standards under the Clean Air Act Amendments of 1977," which was promulgated in 40 CFR 60.16, 44 FR 49222, dated August 21, 1979, ranked sources according to the impact that standards promulgated in 1980 would have on emissions in 1990. Automobile and light-duty truck surface coating operations rank 27 out of 59 on this list of sources to be controlled.

The surface coating operation is an integral part of an automobile or light-duty truck assembly plant, accounting for about one-quarter to one-third of the total space occupied by a typical assembly plant. Surface coatings are applied in two main steps, prime coat and topcoat. Prime coats may be water-based or organic solvent-based. Water-based coatings use water as the main carrier for the coating solids, although these coatings normally contain a small amount of organic solvent. Solvent-based coatings use organic solvents as the coating solid carrier. Currently about half of the domestic automobile and light-duty truck assembly plants use water-based prime coats.

Where water-based prime coating is used, it is usually applied by EDP. The EDP coat is normally followed by a "guide coat," which provides a suitable surface for application of the topcoat. The guide coat may be water-based or solvent-based.

Automobile and light-duty truck topcoats presently being used are almost entirely solvent-based. One or more applications of topcoats are applied to ensure sufficient coating thickness. An oven bake may follow each topcoat application, or the coating may be applied wet on wet.

In 1976, nationwide emissions of VOC from automobile and light-duty truck surface coating operations totaled about 135,000 metric tons. Prime and guide coat operations accounted for about 50,000 metric tons with the remaining 85,000 metric tons being emitted from topcoat operations. This represents almost 15 percent of the volatile organic emissions from all industrial coating operations.

VOC comprise the major air pollutant emitted by automobile and light-duty truck assembly plants. Technology is available to reduce VOC emissions and thereby reduce the formation of ozone and other photochemical oxidants. Consequently, automobile and light-duty truck surface coating operations have been selected for the development of standards of performance.

9.2 SELECTION OF AFFECTED FACILITIES

The prime coat, guide coat, and topcoat operations usually account for more than 80 percent of the VOC emissions from automobile and light-duty truck assembly plants. The remaining VOC emissions result from final topcoat repair, cleanup, and coating of various small component parts. These VOC emission sources are much more difficult to control than the main surface coating line for several reasons. First, water-based coatings cannot be used for final topcoat repair, since the high temperatures required to cure water-based coatings may damage heat sensitive components which have been attached to the vehicle by this stage of production. Second, the use of solvents is required for equipment cleanup procedures. Third, add-on controls, such as incineration, cannot be used effectively on these cleanup operations because they are composed of numerous small operations located throughout the plant. Since prime coat, guide coat, and topcoat operations account for the bulk of VOC emissions from automobile and light-duty truck assembly plants, and control techniques for reducing VOC emissions from these operations are demonstrated, they have been selected for control by standards of performance.

The "affected facility" to which the proposed standards would apply could be designated as the entire surface coating line or each individual surface coating operation. A major consideration in selecting the affected facility was the potential effect that the modification and reconstruction provisions under 40 CFR 60.14 and 60.15, which apply to all standards of performance, could have on existing assembly plants. A modification is any physical or operational change in an existing facility which increases air pollution from that facility. A reconstruction is any replacement of components of an existing facility which is so extensive that the capital cost of the new components exceeds 50 percent of the capital cost of a new facility. For the standard of performance to apply, EPA must conclude that it is technically and economically feasible for the reconstructed facility to meet the standards.

Many automobile and light-duty truck assembly plants that have a spray prime coat system will be switching to EDP prime coat systems in the future to reduce VOC emissions to comply with revised SIP's. The capital cost of this change could be greater than 50 percent of the capital cost of a new surface coating line. If the surface coating line were chosen as the affected facility, and if this switch to an EDP prime coat system were considered a reconstruction of the surface coating line, all surface coating operations on the line would be required to comply with the proposed standards. Most plants would be reluctant to install an EDP prime coat system to reduce VOC emissions if, by doing so, the entire surface coating line might then be required to comply with standards of performance. By designating the prime coat, guide coat, and topcoat operations as separate affected facilities, this potential problem is avoided. Thus, each surface coating operation (i.e., prime coat, guide coat, and topcoat) has been selected as an affected facility in the proposed standards.

9.3 SELECTION OF BEST SYSTEM OF EMISSION REDUCTION

VOC emissions from automobile and light-duty truck surface coating operations can be controlled by the use of coatings having a low organic solvent content, add-on emission control devices, or a combination of the two. Low organic solvent coatings consist of water-based enamels, high solids enamels, and powder coatings. Add-on emission control devices consist of such techniques as incineration and carbon adsorption.

9.3.1 Control Technologies

Water-based coating materials are applied either by conventional spraying or by EDP. Application of coatings by EDP involves dipping the automobile or truck to be coated into a bath containing a dilute water solution of the coating material. When charges of opposite polarity are applied to the dip tank and vehicle, the coating material deposits on the vehicle. Most EDP systems presently in use are anodic systems in which the vehicle is given a positive charge. Cathodic EDP, in which the vehicle is negatively charged, is a new technology which is expanding rapidly in the automobile industry. Cathodic EDP provides better corrosion resistance and requires lower cure temperatures than anodic systems. Cathodic EDP systems are also capable of applying better coverage on deep recesses of parts.

The prime coat is usually followed by a spray application of an intermediate coat, or guide coat, before topcoat application. The guide coat provides the added film thickness necessary for sanding and a suitable surface for topcoat application. EDP can only be used if the total film thickness on the metal surface does not exceed a limiting value. Since this limiting thickness is about the same as the thickness of the prime coat, spraying has to be used for guide and topcoat application of water-based coatings.

Currently, nearly half of domestic automobile and light-duty truck assembly plants use EDP for prime coat application, but only two domestic plants use water-based coatings for guide and topcoat applications.

Coatings whose solids content is about 45 to 60 percent are being developed by a number of companies. When these coatings are applied at high transfer efficiency rates, VOC emissions are significantly less than emissions from existing solvent-based systems. While these high solids coatings could be used in the automotive industry, certain problems must be overcome. The high working viscosity of these coatings makes them unsuitable for use in many existing application devices. In addition, this high viscosity can produce an "orange peel," or uneven, surface. It also makes these coatings unsuitable for use with metallic finishes. Metallic finishes, which account for about 50 percent of domestic demand, are produced by adding small metal flakes to the paint. As the paint dries, these flakes become oriented parallel to the surface. With high solids coatings, the viscosity of the paint prevents movement of the flakes, and they remain randomly oriented, producing a rough surface. However, techniques such as heated application are being investigated to reduce these problems, and it is expected that within a few years high solids coatings will be technically demonstrated for use in the automotive industry.

Powder coatings are a special class of high solids coatings that consist of solids only. They are applied by electrostatic spray and are being used on a limited basis for topcoating automobiles, both foreign and domestic. The use of powder coatings is severely limited, however, because metallic finishes cannot be applied using powder. As with other high solids coatings, research is continuing in the use of powder coatings for the automotive industry.

Thermal incineration has been used to control VOC emissions from bake ovens in automobile and light-duty truck surface coating operations because of the fairly low volume and high VOC concentration in the exhaust stream. Incineration normally achieves a VOC emission reduction of over 90 percent. Thermal incinerators have not, however, been used for control of spray booth VOC emissions. Typically, the spray booth exhaust stream is a high volume stream (95,000 to 200,000 liters per second) which is very low in concentration of VOC (about 50 ppm). Thermal incineration of this exhaust stream would require a large amount of supplemental fuel, which is its main drawback for control of spray booth VOC emissions. There are no technical problems with the use of thermal incineration.

Catalytic incineration permits lower incinerator operating temperatures and, therefore, requires about 50 percent less energy than thermal incineration. Nevertheless, the energy consumption would still be high if used to control VOC emissions from a spray booth. In addition, catalytic incineration allows the owner or operator less choice in selecting a fuel; it requires the use of natural gas to preheat the exhaust gases, since oil firing tends to foul the catalyst. While catalytic incineration is not currently being employed in automobile and light-duty truck surface coating operations for control of VOC emissions, there are no technical problems which would preclude its use on either bake oven or spray booth exhaust gases. The primary limiting factor is the high energy consumption, of natural gas, if used to control emissions from spray booths.

Carbon adsorption has been used successfully to control VOC emissions in a number of industrial applications. The ability of carbon adsorption to control VOC emissions from spray booths and bake ovens in automobile and light-duty truck surface coating operations, however, is uncertain. The presence of a high volume, low VOC exhaust stream from spray booths would require carbon adsorption units much larger than any that have ever been built. For bake ovens in automobile and light-duty truck surface coating operations, a major impediment to the use of carbon adsorption is heat. The high temperature of the bake oven exhaust stream would require the use of refrigeration to cool the gas stream before it passes through the carbon bed. Carbon adsorption, therefore, is not considered a demonstrated technology at this time for controlling VOC emissions from automobile and light-duty truck surface coating operations. Work is continuing within the automotive industry on efforts to apply carbon adsorption to the control of VOC emissions, however, and it may become a demonstrated technology in the near future.

9.3.2 Regulatory Options

Water-based coatings and incineration are two well-demonstrated and feasible techniques for controlling emissions of VOC from automobile and light-duty truck surface coating operations. Based upon the use of these two VOC emission control techniques, the following two regulatory options were evaluated.

Regulatory Option I includes two alternatives which achieve essentially equivalent control of VOC emissions. Alternative A is based on the use of water-based prime coats, guide coats, and topcoats. The prime coat would be applied by EDP. Since the guide coat is essentially a topcoat material, guide coat emission levels as low as those achieved by water-based topcoats should be possible through a transfer of technology from topcoat operations to guide coat operations. Alternative B is based on the use of a water-based prime coat applied by EDP and solvent-based guide coats and topcoats. Incineration of the exhaust gas stream from the topcoat spray booth and bake oven would be used to control VOC emissions under this alternative.

Regulatory Option II is based on the use of a water-based prime coat applied by EDP and solvent-based guide coats and topcoats. In this option, the exhaust gas streams from both the guide coat and topcoat spray booths and bake ovens would be incinerated to control VOC emissions.

These two regulatory options are summarized in Table 9-1 and are compared against a base case consisting of water-based prime coat (EDP) and solvent-based guide coat and topcoat. This base case is representative of VOC emissions from new automobile and light-duty truck surface coating operations capable of meeting existing State Implementation Plan (SIP) emission limits.

9.3.3 Environmental, Energy, and Economic Impacts

Standards based on Regulatory Option I would lead to a reduction in VOC emissions of about 80 percent, and standards based on Regulatory Option II would lead to a reduction in emissions of about 90 percent, compared to VOC emissions from automobile and light-duty truck surface coating operations

Table 9-1. AUTOMOBILE AND LIGHT-DUTY TRUCK SURFACE COATING OPERATIONS EMISSION CONTROL OPTIONS EVALUATED

Emission Control System	Emissions from Model Plant (Metric Tons/Year)		% Reduction From Base Case	
	Automobile	Light-Duty Truck	Automobile	Light-Duty Truck
Base Case 1. Primer - water-based coatings applied by EDP 2. Guide coat - solvent-based coatings applied by air spray 3. Topcoat - solvent-based coatings applied by air spray	1775	1273	--	--
Regulatory Option I(A) 1. Primer - water-based coatings applied by EDP 2. Guide coat - water-based coatings applied by air spray 3. Topcoat - water-based coatings applied by air spray	373	278	79	78
Regulatory Option I(B) 1. Primer - water-based coatings applied by EDP 2. Guide coat - solvent-based coatings applied by air spray with incineration of exhaust from ovens[a] 3. Topcoat - solvent-based coatings applied by air spray with incineration of exhaust from ovens[a]	435	301	76	76
Regulatory Option II 1. Primer - water-based coating applied by EDP 2. Guide coat - solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust[a] 3. Topcoat - solvent-based coatings applied by air spray with incineration of spray booth and oven exhaust[a]	212	147	88	88

[a] Emissions based on incineration with 90% efficiency.

controlled to meet current SIP requirements. Growth projections indicate there will be four new automobile and light-duty truck assembly lines constructed by 1983. Very few, if any, modifications or reconstructions are expected during this period. Based on these projections, national VOC emissions in 1983 would be reduced by about 4,800 metric tons with standards based on Regulatory Option I, and about 5,400 metric tons with standards based on Regulatory Option II. Thus, both regulatory options would result in a significant reduction in VOC emissions from automobile and light-duty truck surface coating operations.

With regard to water pollution, standards based on Regulatory Option II would have essentially no impact. Similarly, standards based on Regulatory Option I(B) would have no water pollution impact. Standards based on Regulatory Option I(A), however, would result in a slight increase in the chemical oxygen demand (COD) of the wastewater discharged from automobile and light-duty truck surface coating operations within assembly plants. This increase is due to water-miscible solvents in the water-based guide coats and topcoats which become dissolved in the wastewater. The increase in COD of the wastewater, however, would be small relative to current COD levels at plants using solvent-based surface coatings and meeting existing SIPs. In addition, this increase would not require the installation of a larger wastewater treatment facility than would be built for an assembly plant which used solvent-based surface coatings.

The solid waste impact of the proposed standards would be negligible. The volume of sludge generated from water-based surface coating operations is approximately the same as that generated from solvent-based surface coating operations. The solid waste generated by water-based coatings, however, is very sticky, and equipment cleanup is more time consuming than for solvent-based coatings. Sludge from either type of system can be disposed of by conventional landfill procedures without leachate problems.

With regard to energy impact, standards based on Regulatory Option I(A) would increase the energy consumption of surface coating operations at a new automobile or light-duty truck assembly plant by about 25 percent. Regulatory Option I(B) would cause an increase of about 150 to 425 percent in energy consumption. Standards based on Regulatory Option II would result in an increase of 300 to 700 percent in the energy consumption of surface coating operations at a new automobile or light-duty truck assembly plant. The range in energy consumption for those options which are based on use of incineration reflects the difference between catalytic and thermal incineration.

The relatively high energy impact of standards based on Regulatory Option I(B) and Regulatory Option II is due to the large amount of incineration fuel needed. Standards based on Regulatory Option II would increase energy consumption at a new automobile and light-duty truck assembly plant by the equivalent of about 200,000 to 500,000 barrels of fuel oil per year, depending upon whether catalytic or thermal incineration was used. Standards based on Regulatory Option I(B) would increase energy consumption by the equivalent of about 100,000 to 300,000 barrels of fuel oil per year.

Standards based on Regulatory Option I(A) would increase the energy consumption of a typical new automobile and light-duty truck assembly plant by the equivalent of about 18,000 barrels of fuel oil per year. Approximately one-third of this increase in energy consumption is due to the use of air conditioning, which is necessary with the use of water-based coatings, and the remaining two-thirds are due to the increased fuel required in the bake ovens for curing water-based coatings.

Growth projections indicate that four new automobile and light-duty truck assembly lines (two automobile and two truck lines) will be built by 1983. Based on these projections, standards based on Regulatory Option I(A) would increase national energy consumption in 1983 by the equivalent of about 72,000 barrels of fuel oil. Standards based on Regulatory Option I(B) would increase national energy consumption in 1983 by the equivalent of 400,000 to 1,200,000 barrels of fuel oil, depending on whether catalytic or thermal incineration were used. Standards based on Regulatory Option II would increase national energy consumption in 1983 by the equivalent of 800,000 to 2,000,000 barrels of fuel oil, again depending on whether catalytic or thermal incineration were used.

The economic impacts of standards based on each regulatory option were estimated using the above mentioned growth projection of four new assembly lines by 1983. Incremental control costs were determined by calculating the difference between the capital and annualized costs of new assembly plants controlled to meet Regulatory Options I(A), I(B), and II, respectively, with the corresponding costs for new plants designed to comply with existing SIPs. Of the four assembly plants projected by 1983, two were assumed to be lacquer lines and the other two enamel lines. There are basic design differences between these two types of surface coatings which have a substantial impact on the magnitude of the costs estimated to comply with standards of performance. Lacquer surface coating operations, for example, require much larger spray booths and bake ovens than enamel surface coating operations. Water-based systems also require large spray booths and bake ovens; thus, the incremental capital cost of installing a water-based system in a plant which would otherwise have used a lacquer system, is relatively low. The incremental capital costs differential, however, would be much larger if the plant had been designed for an enamel system.

Tables 9-2 and 9-3 summarize the economic impacts of the proposed standards on typical size plants. Table 9-2 presents the incremental costs of the various control options for a plant which would have used solvent-based lacquers. Table 9-3 presents similar costs for plants which would have been designed to use solvent-based enamels. While these tables present incremental costs for passenger car plants, light-duty truck plants would have similar cost differentials. In all cases, it is assumed the plants would install a water-based EDP prime system in the absence of standards of performance. Therefore, no incremental costs associated with EDP prime coat operations are included in the costs presented in Tables 9-2 and 9-3. A nominal production rate of 55 passenger cars per hour was assumed for both plants. Tables 9-2 and 9-3 show incremental capitalized and annualized costs per vehicle produced at each new facility. The manufacturers would probably distribute these incremental costs over their entire annual production to arrive at purchase prices for the automobiles and light-duty trucks.

Incremental capital costs for using incineration to reduce VOC emissions from solvent-based lacquer plants to levels comparable to water-based plants are much larger than they are for using incineration on a solvent-based enamel plant. This large difference in costs occurs because lacquer plants have larger spray booth and bake oven areas than enamel plants and, therefore, a larger volume of exhaust gases. Since larger incineration units are required, the incremental capital costs of using incineration to control VOC emissions

Table 9-2. INCREMENTAL CONTROL COSTS [a]

(Compared to the Costs of a Lacquer Plant)

	Regulatory Options				
	I(A)	I(B)		II	
	Water-Based Coatings	Thermal	Catalytic	Thermal	Catalytic
Capital Cost of Control Alternative	$ 720,000	$11,800,000	$15,000,000	$12,800,000	$16,200,000
Annualized Cost of Control Alternative	$1,550,000	$14,500,000	$10,700,000	$15,500,000	$11,500,000
Incremental Cost/Vehicle Produced at this Facility	$7.34	$68.66	$50.66	$73.39	$54.45

[a] Assumes a line speed of 55 vehicles per hour and an annual production of 211,200 vehicles.

Table 9-3. INCREMENTAL CONTROL COSTS[a]

(Compared to the Costs of an Enamel Plant)

	Regulatory Options				
	I(A)	I(B)		II	
	Water-Based Coatings	Thermal	Catalytic	Thermal	Catalytic
Capital Cost of Control Alternative	$10,300,000	$ 4,630,000	$ 5,850,000	$ 5,640,000	$ 7,000,000
Annualized Cost of Control Alternative	$ 3,640,000	$ 5,620,000	$ 4,150,000	$ 6,610,000	$ 4,890,000
Incremental Cost/Vehicle Produced at this Facility	$17.23	$26.61	$19.65	$31.30	$23.15

[a] Assumes a line speed of 55 vehicles per hour and an annual production of 211,200 vehicles.

from a solvent-based lacquer plant are about 15 to 25 times greater than they are for using water-based coatings. Similarly, energy consumption is much greater; hence, the annualized costs of using incineration are about ten times greater than they are for using water-based coatings.

On the other hand, the incremental capital costs of controlling VOC emissions from new solvent-based enamel plants by the use of incineration are only about one-half the incremental capital costs between a new solvent-based enamel plant and a new water-based plant. Due to the energy consumption associated with incinerators, however, the incremental annualized costs of using incineration with solvent-based enamel coatings could vary from as little as 15 percent more to as much as 90 percent more than the annualized costs of using water-based coatings.

While the incremental capital costs of building a plant to use water-based coatings can be larger or smaller than the costs of using incineration, depending upon whether a solvent-based lacquer plant or a solvent-based enamel plant is used as the starting point, the annualized costs of using water-based coatings are always less than they are for using incineration. This is due to the large energy consumption of incineration units compared to the energy consumption of water-based coatings.

Since the incremental annualized costs are less with Regulatory Option I(A) than with Regulatory Option I(B), it is assumed in this analysis that Regulatory Option I(A) would be incorporated at any new, modified, or reconstructed facility to comply with standards based on Regulatory Option I. As noted, four new assembly plants are expected to be built by 1983. The incremental capital cost to the industry for these plants to comply with standards based on Regulatory Option I would be approximately

$19 million. The corresponding incremental annualized costs would be about $9 million in 1983. If standards are based on Regulatory Option II, it is expected that industry would choose catalytic incineration because its annualized costs are lower than thermal incineration. Based on this assumption, the incremental capital costs for the industry under Regulatory Option II would be approximately $42 million, and the incremental annualized costs by 1983 would be about $30 million. For standards based on either Regulatory Option I or Regulatory Option II, the increase in the price of an automobile or light-duty truck that is manufactured at one of the new plants would be less than 1 percent of the base price of the vehicle.

9.3.4 Best System of Emission Reduction

Both Regulatory Options I and II achieve a significant reduction in VOC emissions compared to automobile and light-duty truck assembly plants controlled to comply with existing SIPs, and neither option creates a significant adverse impact on other environmental media. In terms of energy consumption, standards based on Regulatory Option II would have as much as 10 to 25 times the adverse impact on energy consumption as standards based on Regulatory Option I, while only achieving 10 to 15 percent more reductions in VOC emissions. The costs of standards based on Regulatory Option II range from two to three times the costs of standards based on Regulatory Option I. Thus, Regulatory Option I(A), water-based coatings, was selected as the best system of continuous emission reduction, considering costs and nonair quality health, environmental, and energy impacts.

Although water-based coatings are considered to be the best system of emission reduction at the present time, it is very likely that plants built in the future will use other systems to control VOC emissions, such as high solids coatings and powder coatings. High solids coatings are expected to be available by 1982 and will probably be used by most new sources to comply with the VOC emission limitations. Powder coatings are also expected to be available in the future but are not demonstrated at this time.

9.4 SELECTION OF FORMAT FOR THE PROPOSED STANDARDS

A number of different formats could be selected to limit VOC emissions from automobile and light-duty truck surface coating operations. The format ultimately selected must be compatible with any of the three different control systems that could be used to comply with the proposed standards. One control system is the use of water-based coating materials in the prime coat, guide coat, and topcoat operations. Another control system is the use of solvent-based coating materials and add-on VOC emission control devices such as incineration. The third control system consists of the use of high solids coatings. Although the coatings to be used in this system are not demonstrated at this time, research is continuing toward their development; hence, they may be used in the future.

The formats considered were emission limits expressed in terms of: (1) concentration of emissions in the exhaust gases discharged to the atmosphere; (2) mass emissions per unit of production; or (3) mass emissions per volume of coating solids applied.

The major advantage of the concentration format is its simplicity of enforcement. Direct emission measurements could be made using Reference Method 25. There are, however, two significant drawbacks to the use of this format. Regardless of the control approach chosen, emission testing would be required for each stack exhausting gases from the surface coating operations (unless the owner or operator could demonstrate to the

- 0.10 kilogram of volatile organic compounds per liter of applied coating solids from prime coat operations
- 0.84 kilogram of volatile organic compounds per liter of applied coating solids from guide coat operations
- 0.84 kilogram of volatile organic compounds per liter of applied coating solids from topcoat operations

In all three limits, the mass of VOC is expressed as mass of carbon in accordance with Reference Methods 24 (Candidate 1) and 25. These emission limits are based on the use of water-based coating materials in the prime coat, guide coat, and topcoat operations. Water-based coating data were obtained from plants which were using these materials as well as the vendors who supply them. These data were used to calculate VOC emission limits using a procedure similar to proposed Reference Method 24 (Candidate 1). A transfer efficiency of 40 percent was then applied to the values obtained for guide coat and topcoat emissions. This efficiency was determined to be representative of a well operated air atomized spray system. The CTG recommended limits are based on the use of the same coating materials as the proposed standards. The limits in the CTG are expressed in pounds of VOC per gallon of coating (minus water) used in the EDP system or the spray device. The limits in this proposed standard, however, are referenced to the amount of coating solids which adhere to the vehicle body. Therefore, to compare the limits in the CTG to those proposed here, it is necessary to account for the solids content of the coating and the efficiency of applying the guide coat and topcoat to the vehicle body. Consideration of transfer efficiency is significant because the recommended standards can be met by using high solids content coating materials if the amount of overspray is kept to a minimum. Since this format provides equivalency determinations for systems

VOC emissions per unit of production. This format, however, would not account for differences in surface coating requirements for different vehicles due to size and configuration. In addition, manufacturers of larger vehicles would be required to reduce VOC emissions further than manufacturers of smaller vehicles.

A format of mass of VOC emissions per volume of coating solids applied also has the advantage of not requiring stack emission testing unless add-on emission control devices are used to comply with the standards rather than water-based coatings. The introduction of dilution air into the exhaust stream would not present a problem with this format. The problem of varying vehicle sizes and configurations would be eliminated since the format is in terms of volume of applied solids regardless of the surface area or number of vehicles coated. This format would also allow flexibility in selection of control systems, for it is usable with any of the control methods. Since this format overcomes the varying dilution air and vehicle size problems inherent with the other formats, it has been selected as the format for the proposed standards. In order to use a format which is in terms of applied solids, the transfer efficiency of the application devices must be considered. Transfer efficiency is an important factor because as efficiency decreases, more coating material is used and VOC emissions increase. Equations have been developed to use this format with water-based coating materials as well as with solvent-based coating materials in combination with high transfer efficiencies and/or add-on emission controls devices. These equations are included in the proposed standards.

9.5 SELECTION OF NUMERICAL EMISSION LIMITS

The numerical emission limits selected for the proposed standard are as follows:

Administrator's satisfaction that testing of representative stacks would give the same results as testing all the stacks). This testing would be time consuming and costly because of the large number of stacks associated with automobile and light-duty truck surface coating operations. Another potential problem with this format is the ease of circumventing the standards by the addition of dilution air. It would be extremely difficult to determine whether dilution air were being added intentionally to reduce the concentration of VOC emissions in the gases discharged to the atmosphere, or whether the air was being added to the application or drying operation to optimize performance and maintain a safe working space.

A format of mass of VOC emissions per unit of production relates emissions to individual plant production on a direct basis. Where water-based coatings are used, the average VOC content of the coating materials could be determined by using Reference Method 24 (Candidate 1 or Candidate 2). The volume of coating materials used and the percent solids could be determined from purchase records. VOC emissions could then be calculated by multiplying the VOC content of the coating materials by the volume of coating materials used in a given time period and by the percentage of solids, and dividing the result by the number of vehicles produced in that time period. This would provide a VOC emission rate per unit of production. Consequently, procedures to determine compliance would be direct and straightforward, although very time consuming. This procedure would also require data collection over an excessively long period of time.

Where solvent-based coatings were used with add-on emission control devices, stack emission tests could be performed to determine VOC emissions. Dividing VOC emissions by the number of vehicles produced would again yield using solvent-based coating materials in combination with high transfer efficiencies and/or add-on control devices, it allows flexibility in selection of control systems.

As discussed in previous sections, there are two types of EDP systems. Anodic EDP was the first type developed for use in automotive surface coating operations. Cathodic EDP is the second type and is a recent technology improvement which results in greater corrosion resistance. Consequently, nearly 50 percent of the existing EDP operations use cathodic systems, and continued changeovers from anodic to cathodic EDP are expected. Since cathodic EDP produces a coating with better corrosion resistance, the proposed standards are based on the best available cathodic EDP systems.

The coating material on which the EDP emission limit was based is presently in limited production use. Although this low solvent content material is currently available only in limited quantities, it is expected to be available in sufficient quantities for use in all new or modified sources before promulgation of the standards. The final promulgated standards will be based on this low solvent content material, rather than the EDP material commonly used now, if it is determined to be widely available at that time.

The emission limit for guide coat operations is based on a transfer of technology from topcoat operations. The guide coat is essentially a topcoat material, without pigmentation, and water-based topcoats are available which can comply with the proposed limits. Hence, the same emission limit is proposed for the guide coat operation as for the topcoat operation.

Because of the elevated temperatures present in the prime coat, guide coat, and topcoat bake ovens, there may be additional amounts of "cure volatile" VOC emitted. These "cure volatile" emissions are present only at high temperatures and are not measured in the analysis which is used to determine the VOC content of coating materials. Cure volatile emissions, however, are believed to constitute only a small percentage of total VOC emissions. Consequently, due to the complexity of measuring and controlling cure volatile emissions, they would not be considered in determining compliance with the proposed standards.

A large number of coating materials are used in topcoat operations, and each may have a different VOC content. Hence, an average VOC content of all the coatings used in this operation would be computed to determine compliance with the proposed standards. Either of two averaging techniques could be used for computing this average. Weighted averages provide very accurate results but would require keeping records of the total volume and percent solids of each different coating used. Arithmetic averages are not always as accurate; however, they are much simpler to calculate. In the case of topcoat operations, normally 15 to 20 different coatings are used, and the VOC content for most of these coatings is in the same general range. Therefore, an arithmetic average would closely approximate the values obtained from a weighted average. An arithmetic average would be calculated by summing the VOC content of each surface coating material used in a surface coating operation (i.e., guide coat or topcoat), and dividing the sum by the number of different coating materials used. Arithmetic averages are also consistent with the approach being incorporated into some revised SIPs.

For the EDP process, however, an arithmetic average VOC content is not appropriate to determine compliance with the proposed standards. In an EDP system, the coating material applied to an automobile or light-duty truck body is replaced by adding fresh coating materials to maintain a relatively constant concentration of solids, solvent, and fluid level in the EDP coating tank. Three different types of materials are usually added in separate streams--clear resin, pigment paste, and solvent.

The clear resin and pigment paste are very low in VOC content (i.e., 10 percent or less), while the solvent is very high in VOC content (i.e., 90 percent or more). The solvent additive stream is only about 2 percent of the total volume added. Consequently, an arithmetic average of the three streams seriously misrepresents the actual amount of VOC added to the EDP coating tank. Weighted averages, therefore, were selected for determining the average VOC content of coating materials applied by EDP.

If an automobile or light-duty truck manufacturer chooses to use a control technique other than water-based coatings, the transfer efficiency of the application devices used becomes very important. As transfer efficiency decreases, more coating material is used, and VOC emissions increase. Therefore, transfer efficiency must be taken into account to determine equivalency to water-based coatings.

Electrostatic spraying, which applies surface coatings at high transfer efficiencies, can in many industries be used with water-based coatings if the entire paint handling system feeding the atomizers is insulated electrically from ground. Otherwise, the high conductivity of the water involved would ground out and make ineffective the electrostatic effect. In the case of the coating of automobiles, however, because of the large number of colors involved, the high frequency and speed of color changes required, the large volume of coatings consumed per shift, and the large number of both automatic and manual atomizers involved, it is not technically feasible to combine water-based coatings and electrostatic methods for reasons of complexity, cost and personnel comfort. Consequently, water-based surface coatings are applied by air-atomized spray systems at a transfer efficiency of about 40 percent. The numerical emission limits included in the proposed standards were developed based on the use of water-based surface coatings applied at a 40 percent transfer efficiency. Therefore, if surface coatings are applied at greater than 40 percent transfer efficiency, surface coatings with higher VOC contents may be used with no increase in VOC emissions to the atmosphere. Transfer efficiencies for various means of applying surface coatings have been estimated, based on information obtained from industries and vendors, as follows:

Application Method	Transfer Efficiency
Air Atomized Spray	40 percent
Manual Electrostatic Spray	75 percent
Automatic Electrostatic Spray	95 percent
Electrodeposition (EDP)	100 percent

These values are estimates which reflect the high side of expected transfer efficiency ranges, and therefore, are intended to be used only for the purpose of determining compliance with the proposed standards.

Frequently, more than one application method is used within a single surface coating operation. In these cases, a weighted average transfer efficiency, based on the relative volume of coating sprayed by each method, will be estimated. These situations are likely to vary among the different manufacturers and the estimates, therefore, will be subject to approval by the Administrator on a case-by-case basis.

9.6 SELECTION OF MONITORING REQUIREMENTS

Monitoring requirements are generally included in standards of performance to provide a means for enforcement personnel to ensure that emission control measures adopted by a facility to comply with standards of performance are properly operated and maintained. Surface coating operations which have achieved compliance with the proposed standards without the use of add-on VOC emission control devices would be required to monitor the average VOC content (weighted averages for EDP and arithmetic averages for guide coat and topcoat) of the coating materials used in each surface coating operation. Generally, increases in the VOC content of the coating materials would cause VOC emissions to increase. These increases could be caused by the use of new coatings or by changes in the composition of existing coatings. Therefore, following the initial performance test, increases in the average VOC content of the coating materials used in each surface coating operation would have to be reported as excess emissions on a quarterly basis.

Where add-on control devices, such as incinerators, were used to comply with the proposed standards, combustion temperatures would be monitored. Following the initial performance test, decreases in the incinerator combustion temperature would be reported as excess emissions on a quarterly basis.

9.7 PERFORMANCE TEST METHODS

Reference Method 24, "Determination of Volatile Organic Compound Content of Paint, Varnish, Lacquer, or Related Products," is proposed in two forms; Candidate 1 and Candidate 2. Candidate 1 leads to a determination of VOC content expressed as mass of carbon. Candidate 2 yields a determination of VOC content measured as mass of volatile organics. Either of these candidates is compatible with the proposed standards, and the decision as to which candidate will be used depends on the final format selected for the standards. Reference Method 25, "Determination of Total Gaseous Nonmethane Volatile Organic Compound Emissions," was proposed as the test method to determine the percentage reduction of VOC emissions achieved by add-on emission control devices.

9.8 MODIFICATIONS AND RECONSTRUCTIONS

During the development of the standards, the automobile industry expressed concern that changes to assembly plants made only for the purpose of annual model changeovers would be considered a modification or reconstruction as defined in the Code of Federal Regulations, Title 40, Parts 60.14 and 60.15 (40 CFR 60.14 and 60.15). A modification is any physical or operational change in an existing facility which increases air pollution from that facility. A reconstruction is any replacement of components of an existing facility which is so extensive that the capital cost of the new components exceeds 50 percent of the capital cost of a new facility. In general, modified and reconstructed facilities must comply with standards of performance. According to the available information, changes to coating lines for annual model changeovers do not cause emissions to increase significantly. Further, these changes would normally not require a capital expenditure that exceeds the 50 percent criterion for reconstruction. Hence, it is very unlikely that these annual facility changes would be considered either a modification or a reconstruction. Therefore, the proposed standards state that changes to surface coating operations made only to accommodate annual model changeovers are not a modification or reconstruction. In addition, by exempting annual model changeovers, enforcement efforts are greatly reduced with little or no adverse environmental impact.

APPENDIX A

EVOLUTION OF PROPOSED STANDARDS

This study to develop proposed standards of performance for new surface coating operations within the automotive industry began in 1973 under the direction of the Office of Air Quality Planning and Standards (OAQPS), Emission Standards and Engineering Division (ESED) with Mr. Richard B. Atherton of the Industrial Studies Branch (ISB) as the lead engineer. In June 1975, EPA authorized DeBell and Richardson to continue the study, contract number 68-02-2062, under the direction of Mr. Dave Patrick of the Chemical Petroleum Branch (CPB). On March 30, 1976, Mr. James Berry (CPB) replaced Mr. Dave Patrick as lead engineer. Table A-1 lists the major events that occurred between project initiation and October 1978, when Acurex Corporation was retained by EPA to complete the study under contract number 68-02-3064 with Mr. Sims L. Roy as the lead engineer, OAQPS, ESED of the Standards Development Branch.

The overall objective of this study was to compile and analyze data in sufficient detail to substantiate standards of performance. To accomplish this objective, the investigators first acquired the necessary technical information on: (1) coating operations and processes; (2) the release and controllability of organic emissions into the atmosphere by this source; and (3) the costs of demonstrated control techniques. A literature search was conducted and data obtained from the following:

- U.S. Department of Commerce
- Federal Trade Commission Quarterly Reports
- Society of Manufacturing Engineers

Table A-1. MAJOR EVENTS, YEAR 1974 - MID 1978

Equipment Manufacturers Telephone Survey	8/11/75
Equipment Suppliers Telephone Survey	8/15/75
Surface Coating Equipment Manufacturers	8/20/75
Office of Management and Budget (OMB) Approval of Questionnaire	9/26/75
Industry Completion of Questionnaires	12/75 - 5/76
Meeting to Discuss Economic Impacts	2/1/76
Draft Document, "Study to Support NSPS for Automobile and Light-Duty Trucks," Published by EPA	6/1/77
EPA Memo Suggesting Standards of Performance Sent to Industry	8/77
National Air Pollution Control Techniques Advisory Committee (NAPCTAC) Meeting	9/27/77
Working Group Meeting	10/6/77
JACA Corporation Retained by EPA to Study Economic Impacts	11/77
PEDCo Retained by EPA to Prepare an Economic Impact Analysis	4/26/78
Centec Consultants, Inc. Retained by EPA to Revise Draft Document	7/1/78
Meetings with Various Equipment Manufacturers, Suppliers and Auto Makers and State Agencies (See Tables A-2, A-3, A-4, A-5)	

- U.S. Government Printing Office
- National Technical Information Service
- Various Trade Journals

Through an extensive telephone survey, data were obtained from suppliers and manufacturers of control equipment and coating materials used within the surface coating industry. Contacts with trade associations, regional EPA offices, and State air pollution authorities provided additional technical information. An EPA questionnaire (industry survey) was approved by OMB in September 1975 and distributed throughout the automotive industry to obtain information on plant size, control techniques, production capacities and emissions data. Direct contacts were supplemented by plant tours and meetings with the automotive industry to gain firsthand information on control techniques and emissions data.

The second major step in this study was to determine the environmental and economic impacts of various alternative regulatory options. The environmental impacts of the various alternative regulatory options were determined by comparing the projected emissions under each option with those for the base case. The economic analysis was supported by examining various automotive plants, contacting the Department of Commerce, and reviewing Wards' Automotive Yearbooks and various trade journals.

On June 1, 1977, EPA published a draft document, "Study to Support an NSPS for Automobile and Light-Duty Trucks." A memo suggesting standards of performance was distributed throughout the automotive industry in August 1977. DeBell and Richardson presented the draft study to the NAPCTAC meeting held in Alexandria, Virginia, on September 27 and 28, 1977. On October 6, 1977, a working group meeting was held to discuss industry comments raised at the NAPCTAC meeting.

Upon receipt of this project in October 1978, Acurex began to review and revise the previous documents in light of the comments made by the Working Group and NAPCTAC, and the information received from industry since the preparation and public presentation of the first draft.

Additional data were obtained from Ransburg Corporation on transfer efficiencies and from General Motors on paint content. The existing document was extensively revised from December 1978 to mid-May 1979. The complete Background Information Document (BID) and the FEDERAL REGISTER notice of the proposed regulation were prepared and submitted to the EPA Steering Committee on May 18, 1979, and the Assistant Administrators for concurrence on July 18, 1979. The following tables list the various contacts that were made during investigation of this study:

- Table A-2. Suppliers and Manufacturers
- Table A-3. State Agencies
- Table A-4. Plant Visits
- Table A-5. Meetings with the Automotive Industry

Table A-2. SUPPLIERS AND MANUFACTURERS CONTACTED

ADSOX
AER Corporation
Binks
Calgon Activated Carbon Division
Combustion Equipment Associates
DeVilbiss Company
Dexter Corporation
Dow-Corning Corporation
E.I. DuPont de Nemours and Company
Electrostatic Equipment Corporation
George Koch & Sons, Incorporated
High Voltage Engineering Corporation
Hoyt Solvent Recovery Systems
Interrad
Jensen, Incorporated
Lilly Industrial Coatings, Incorporated
Matthey Bishop, Incorporated
Moller Engineering
Nordson Corporation
Polychrome
PPG Industries
Programmed Coating
Ransburg Corporation
RaySolv Incorporated
Regenerative Environmental Equipment Co., Incorporated (Reeco)
Sealectro Corporation
Sherwin Williams
Troy Chemical Corporation
Vulcan-Cincinnati
W.R. Grace and Company
W.S. Rockwell

Table A-3. STATE AGENCIES CONTACTED

California Air Resources Board
Sacramento, CA

Bay Area Air Pollution Control District
San Francisco, CA

Air Pollution Control District
Louisville, KY

State of Maryland
Department of Health and Mental Hygiene
Baltimore, MD

Department of Environmental Protection
Hartford, CT

Massachusetts Division of Environmental
  Quality Engineering
Boston, MA

State of New Jersey
Department of Environmental Protection
Trenton, NJ

Commonwealth of Virginia
State Air Pollution Control Board
Virginia Beach, VA

Table A-4. SURFACE COATING OPERATIONS VISITED DURING PREPARATION OF THE BACKGROUND INFORMATION DOCUMENT

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
Ford Motor Corp. Wayne, MI	3/27/73	Gather general information on Ford's truck plant and the Wayne auto assembly plant.
General Motors Corp. Detroit, MI	3/28/73	Fleetwood plant; gather general information.
Chrysler Corp. Detroit, MI	3/29/73	Observe the sources of emissions and gather general information.
Ford Motor Corp. Pico Rivera, CA	7/11/73	Observe bake ovens.
General Motors Corp. Southgate/Van Nuys, CA	7/12/73	Observe bake ovens.
General Motors Corp. Norwood, OH	9/29/74	Familiarize EPA personnel with the surface coating operations within the automotive industry.
Ford Motor Corp. Atlanta, GA	2/18/75	Familiarize EPA personnel with the surface coating operations within automotive industry.
Ford Motor Corp. Metuchen, NJ	5/14/75	Powder and conventional coating operations.
General Motors Corp. Framingham, MA	9/9/75	Observe water-based primer process (EDP) and to discuss powder coatings.
Ford Motor Corp. Norfolk, VA	9/12/75	Pickup trucks are assembled at this location. Gather general information.
Roper Eastern Co. Baltimore, MD	9/26/75	Observation of conventional coil coating operations
General Motors Corp. Southgate/Van Nuys, CA	10/7-8/75	Southgate and Van Nuys plants are the only full scale automotive assembly plants in the U.S. employing water-based paints.
Mack Trucks Allentown/Macunigie, PA	10/10/75	Gather general information.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
Chrysler Corp. Newark, DE	10/14/75	Epoxy prime coat and acrylic enamel topcoat operations.
White Motor Corp. Exton, PA	10/15/75	Gather general information.
General Motors Corp. Baltimore, MD	10/16/75	Enamel is used for prime coat and lacquer for topcoat.
General Motors Corp. Wilmington, DE	10/17/75	Chevettes are assembled at this location. The Chevette requires considerable inside painting.
Checker Motors Corp. Kalamazoo, MI	11/11/75	Checker Motors manufactures taxicabs. Checker Motors has had contracts with one or more of the other auto makers to paint cars and produce body parts.
Ford Motor Corp. Wayne, MI	11/13/75	Observe conventional coating operations.
American Can Co. Hillside, NJ	12/2/75	Gather general information.
American Can Co. Edison, NJ	12/2/75	This location produces two-piece cans which are coated with solvent-based materials. The plant is equipped with incinerators.
Stanley Works Co. New Britain, CT	12/4/75	Observation of coil coating operations
General Dynamics Co. Corvair Division San Diego, CA	12/7/75	One of three U.S. aircraft industries employing new technology, water-based technology.
Chrysler Corp. Detroit, MI	12/8/75	Longest automobile assembly line in the world. Considered a good candidate for general information purposes.
Chrysler Corp. Detroit, MI	12/8/75	Autophoretic coating is employed at this plant.
General Motors Corp. Detroit, MI	12/9/75	Fleetwood plant; this coating operation produces GM's highest quality paint job.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
General Motors Corp. Pontiac, MI	12/10/75	Two identical production lines are housed at this location. LDL (solvent-based low dispersion lacquer) was employed at this site with the 1976 models.
Douglas Aircraft Co. Long Beach, CA	12/10/75	To view application of conventional solvent solution coatings.
Virco Manufacturing Gardena, CA	12/10/75	Observe Virco's powder coating line which is fitted with an incinerator.
Rockwell International Saberline Division El Segundo, CA	12/11/75	Conventional coating of aircraft with solvent-based materials.
General Motors Corp. Pontiac, MI	12/12/75	Modern truck assembly plant, to gather general information.
California Finished Metals, Inc. Cucamonga, CA	12/12/75	Obtain data on afterburners.
Supracote Inc. Cucamonga, CA	12/12/75	Obtain data on afterburners.
International Harvester Co. Rock Island, IL	12/15/75	Observation of the manual electrostatic spray operations.
International Harvester Co. East Moline, IL	12/15/75	Application of one coat modified AKYD solvent-based paints with electrostatic spray was observed.
Deere Co. Waterloo, IA	12/17/75	Undercoating of all tractor parts, except chassis, is applied with water-based paint by using the EDP process.
Republic Steel Co. Youngstown, OH	12/17/75	Observe conventional coil coating operations.
Armco Steel Corp. Middletown, Ohio	12/18/75	Observe conventional coil coating operations.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
Winnebago Industries Forest City, IA	12/18/75	Molding and trim on all Winnebago mobile homes are electrostatically sprayed with powder. Cabs are electrostatically coated with liquid paints.
Allis Chalmers Corp. La Porte, IN	12/19/75	Farm machinery is coated with water-based paints.
The Boeing Co. Everett, WA	12/21/75	Observe application of water-based coatings.
Hackney & Sons (East) Washington, NC	12/22/75	Beverage trucks are topcoated with acrylic enamels which are metallic and nonmetallic.
Modern Materials Corp. Detroit, MI	1/7/76	Coil coating using water-based materials.
Litho-Strip Co. Glenview, IL	1/8/76	Solvent-based coating materials are employed on their coil coating lines.
Signode Corp. Bridgeview, IL	1/8/76	Company manufactures steel strappings which are coated with epoxy-based materials.
Chrysler Corp. Detroit, MI	1/9/76	Trucks are topcoated with solvent-based coatings at this site.
Ford Motor Corp. Wayne, MI	1/9/76	Truck plant, solvent-based primer coating operation. Small parts are powder coated with an acrylic.
Simmons Co. Munster, IN	1/14/76	Metal drawers are coated with high solids.
Food Machinery Co. Tupello, MS	1/14/76	Conveyor parts are powder coated.
Ford Motor Corp. Metuchen, NJ	1/15/76	Observe powder coating operations.
Lau Industries Dayton, OH	1/15/76	Blower and fan components are coated with water reducible alkyd paint.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
American Can Co. Baltimore, MD	1/16/76	Solvent-based inner lacquer is employed. The base coat is a high solids solvent-based material.
Continental Can Co. Sparrows Point, MD	1/16/76	Obtain information in ultraviolet curing.
H.K. Porter Co., Inc. Lynchburg, VA	1/16/76	Observe coating operations of transformer parts.
Teledyne Rodney Metals New Bedford, MA	1/23/76	Observe and discuss the coil coating operation of the company. No primer is applied, only a single solvent-based topcoat.
Bilco, Inc. West Haven, CT	1/28/76	Observe the coating operation of metal doors.
Levolor Lorenthen, Inc. Hoboken, NJ	1/29/76	Observation of the coil coating operation.
Sun Shipbuilding & Dry Dock Chester, PA	1/30/76	Coating materials are solvent-based.
Lyon Metal Products, Inc. Aurora, IL	2/3/76	Metal furniture is coated with solvent-based materials.
Steelcase Co. Grand Rapids, MI	2/4/76	Metal furniture is powder coated at this plant.
Ford Motor Corp. Oakville Ontario, Canada	2/5/76	Plant has two assembly lines, one truck and one automobile line. Water-based coatings are employed.
Roll Coater, Inc. Kingsbury, IN	2/9/76	Gather information on incinerators and observe coil coating operations.
International Harvester Fort Wayne, IN	2/10/76	Truck plant, observe surface coating operations of Scouts (light-duty trucks).
Norfolk Shipbuilding & Dry Dock Norfolk, VA	2/11/76	The most commonly used coating materials are solvent-based.
Newport News Shipbuilding Newport News, VA	2/12/76	Practically all coating materials are solvent-based.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
General Products Mayfield, VA	2/12/76	Steel exterior entrance doors are topcoated with acrylic which is electrostatically sprayed.
Keller Industries Milford, VA	2/12/76	Aluminum patio doors and windows are coated with a modified polyester water-based material.
General Products Fredericksburg, VA	2/12/76	Observe electrostatic spray and miscellaneous spray booths.
Keller Industries Milford, VA	2/12/76	Aluminum patio doors and windows are coated with a modified polyester water-based material.
Crown Cork and Seal Co., Inc. Philadelphia, PA	2/13/76	Steel sheets for cans, the bulk of the coating and decorating materials are solvent-based. Water-based inner coating materials are also used.
Central Chevrolet Co. West Springfield, MA	2/16/76	Auto body repair shop which uses solvent-based materials. Lacquer is employed for touch-ups and enamel for whole paint jobs.
Endure a Lifetime Miami, FL	2/16/76	Laminated doors are touched up with an air dry enamel which is applied with a manual spray.
Connecticut Auto Body Bloomfield, CT	2/17/76	Acrylic lacquer is used for refinishing doors and fenders.
Houser Auto Body Springfield, MA	2/17/76	Observe a typical plant spraying operation.
Raybestos Manhattan, Inc. Mayheim, PA	2/17/76	To view add-on equipment which is used to reduce hydrocarbon emissions.
Viking Wire Danbury, CT	2/19/76	Plant uses a catalytic adsorber and incineration.
Steiber Cycle Corp. Medford, NY	2/24/76	Observe powder coating of bicycle frames.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
Continental Can Co. Portage, IN	2/24/76	Discuss and observe the use of incinerators.
Continental Can Co. Weirton, WV	2/25/76	Ultraviolet curing technology employed at this plant.
Earl Scheib Auto Body Shops Providence, RI	2/25/76	Observe a typical auto refinishing operation.
Goodman Bros. Mfg. Co. Philadelphia, PA	2/25/76	Metal hospital beds are powder coated at this plant.
Burting Co. Philadelphia, PA	2/25/76	Observation of powder coating outdoor metal furniture.
Joy Manufacturing Co. Michigan City, IN	2/25/76	Observe spray painting of compressor parts.
Earl Scheib Auto Body Shops West Haven, CT	2/26/76	Observation of an auto refinishing operation.
Nordson Corp. Amherst, OH	2/26/76	Pump components for spray equipment are powder coated at this plant.
American Can Co. Lemoyne, PA	2/27/76	Observe and discuss the use of a carbon adsorber for solvent recovery.
Essex International Fort Wayne, IN	3/4/76	Observe wire coating operations.
H.D. Hudson Co. Hastings, MN	3/3/76	Insecticide spray equipment is powder coated at this plant.
Peachtree Door St. Joseph, MO	3/3/76	Observation of two finishing lines, EDP and electrostatic spray
REA Magnet Wire Fort Wayne, IN	3/4/76	Magnet wire coating operation was observed.
General Motors Corp. Southgate, CA	3/10/76	Water-based coating operations are employed at this plant.
General Motors Corp. Van Nuys, CA	3/11/76	Water-based topcoating operations are employed at this site.

Table A-4 (continued)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
Ford Motor Corp. Milpitas, CA	3/12/76	Observation of typical coating operations. Incinerators are housed at this site (auto and truck plant).
American Motors Corp. Mishawaka, IN	3/15/76	Bus manufacturing, observe coating operations and gather general information.
General Electric Co. Schenectady, NY	3/16/76	Observation of wire coating operations
Phelps Dodge Magnet Wire Fort Wayne, IN	3/19/76	Observation of wire coating operations
National Can Corp. Danbury, CT	3/24/76	Observation of typical coating operations of cans. Obtain information on incinerators.
Chicago Magnet Wire Elks Grove Village, IL	4/7/76	Observation of wire coating operations.
Dupont Corp. Fairfield, CT	4/30/76	To obtain information on both fabric coating and solvent emission control by catalytic incineration.
General Electrical Corp. Louisville, KY	5/4/76	Large appliances are powder coated at this site. Observe EDP coating facilities.
Hazen Paper Co. Holyoke, MA	5/19/76	Solvent-based coating line equipped with an incinerator.
Brown-Bridge Mills Troy, Ohio	6/30/76	To view the paper coating operation and carbon adsorption system.
Scott Graphics South Hadley, MA	7/1/76	Discuss solvent recovery process and observe the carbon adsorption system and paper coating operation.
Fasson Co. Painesville, OH	7/14/76	To view the paper coating operation and carbon adsorption system.
Chrysler Corp. Belvidere, IL	10/12/76	Plant represents the typical adhesives (solvent-based) operation.

Table A-4 (concluded)

COMPANY/LOCATION	VISIT DATE(S)	TECHNOLOGY OBSERVED AND/OR PURPOSE OF TRIP
General Motors Corp. Ypsilanti, MI	10/10/76	Compact sized cars manufactured at this site. Plant employs the operation of typical adhesives.
Ford Motor Corp. Dearborn, MI	11/11/76	Sporty compact cars manufactured at this site. Typical adhesives are used at this location.
Sebring-Vanguard Corp. Sebring, FL	3/1/77	Largest producer of electric cars in the world. Determine the ability of small automobile or light-duty truck producers to meet an NSPS that might be promulgated for the auto industry.
General Motors Corp. Van Nuys/South Gate, CA	9/25 and 9/26/78	Observe water-based painting operations.
Ford Motor Corp. Dearborn, MI	5/29 and 5/30/79	Observe a pilot carbon adsorption program.
General Motors Corp Oklahoma City, OK	8/22 and 8/23/79	Observe water-based coating operations.

Table A-5. MEETINGS WITH THE AUTOMOTIVE INDUSTRY[a]

Date	Association[b] or Firm	Other Attendees[a,b]	Report Date
3/31/77	MVMA	AMC, Chrysler Corp., Ford Motor, and GM	4/4/77
4/6/77	GM	GM	4/14/77
12/19/77	GM		1/10/78
3/28/78	GM		4/3/78
4/21/78	GM		5/18/78
8/2/78	Ford		8/29/78
8/14/79	GM		8/17/79

[a] All meetings were held in Durham, North Carolina unless specified otherwise, and were attended by representatives of EPA.

[b] AMC - American Motors Corporation
GM - General Motors
MVMA - Motor Vehicle Manufacturers Association.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
1. Background and Description of the Proposed Action.	
- Describe the recommended or proposed action and its purpose.	The proposed regulations are summarized in Chapter 1 and Chapter 9. The statutory basis for the proposed regulatons (Section 111 of the Clean Air Act, as amended) is discussed in Chapter 9.
2. Alternatives to the Proposed Action.	
- Describe and objectively weigh reasonable alternatives to the proposed action, to the extent such alternatives are permitted by the law . . . For use as a reference point to which other actions can be compared, the analysis of alternatives should include the alternative of taking no action, or of postponing action. In addition, the analysis should include alternatives having different environmental impacts, including proposing standards, criteria, procedures, or actions of varying degrees of stringency. When appropriate, actions with similar environmental impacts but based on different technical approaches should be discussed. This analysis shall evaluate alternatives in such a manner that reviewers can judge their relative desirability.	The Clean Air Act amendments of 1977 require EPA to revise existing regulations under Section 111 of the Act. Alternative control systems are discussed in Chapter 4. The environmental impact of different levels of control is discussed in Chapter 7. The economic impact of alternative control levels and systems is discussed in Chapter 8. Alternative formats for the proposed regulations are discussed in Chapter 9.

APPENDIX B (CONTINUED)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
- The analysis should be sufficiently detailed to reveal the Agency's comparative evaluation of the beneficial and adverse environmental, health, social, and economic effects of the proposed action and and each reasonable alternative.	The environmental and energy impacts of the proposed regulations are discussed in Chapter 1, Chapter 7, Chapter 8, and Chapter 9. Economic impacts are discussed in Chapter 1 and Chapter 8. The inflationary impact is discussed in Chapter 1 and Chapter 8. The socioeconomic impact is discussed in Chapter 8.
	Section 111 of the Clean Air Act does not require EPA to directly consider health effects in establishing the level of new source performance standards.
- Where the authorizing legislation limits the Agency from taking certain factors into account in its decision making, the comparative evaluation should discuss all relevant factors, but clearly identify those factors which the authorizing legislation requires to be the basis of the decision making.	The legislative history of new source performance standards is presented in Chapter 2. The proposed regulations are required by the Clean Air Act amendments of 1977, as discussed in Chapter 9.
- In addition, the reasons why the proposed action is believed by the Agency to be the best course of action shall be explained.	The rationale for the proposed regulations is presented in Chapter 9.

APPENDIX B (CONTINUED)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
3. Environmental Impact of the Proposed Action.	
A. Primary impact	
- Primary impacts are those that can be attributed directly to the action, such as reduced levels of specific pollutants brought about by a new standard and the physical changes that occur in the various media with this reduction.	The primary environmental impacts on mass emissions and ambient air quality are discussed in Chapter 7 and Chapter 9.
B. Secondary impact	
- Secondary impacts are indirect or induced impacts. For example, mandatory reduction of specific pollutants brought about by a new standard could result in the adoption of control technology that exacerbates another pollution problem and would be a secondary impact.	Secondary impacts on air and water quality, solid waste disposal, noise, and energy conservation are discussed in Chapter 1, Chapter 7 and Chapter 8.
4. Other Considerations.	
A. Adverse impacts which cannot be avoided should the proposal be implemented. Describe the kinds and magnitudes of adverse impacts which cannot be reduced	No potential adverse side effects are expected. A more detailed discussion is presented in Chapter 9. Potential adverse economic impacts are discussed in Chapter 8.

APPENDIX B (CONTINUED)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
in severity to an acceptable level or which can be reduced to an acceptable level but not eliminated. These may include air or water pollution, damage to ecological systems, reduction in economic activities, threats to health, or undesirable land use patterns. Remedial, protective, and mitigative measures which will be taken as part of the proposed action shall be identified.	
B. Relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. Describe the extent to which the proposed action involves trade-offs between short-term environmental gains at the expense of long-term losses or vice versa and the extent to which the proposed action forecloses future options. Special attention shall be given to effects which pose long-term risks to health or safety. In addition, the timing of the proposed action shall be explained and justified.	No trade-offs are expected. This subject is discussed in more detail in Chapter 9.
C. Irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.	There would be no irreversible and irretrievable commitments of resources as a result of the proproposed regulations. See Chapter 7.

APPENDIX B (CONCLUDED)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
Describe the extent to which the proposed action curtails the diversity and range of beneficial uses of the environment. For example, irreversible damage can result if a standard is not sufficiently stringent.	
D. A discussion of problems and objections raised by other Federal, State, and local agencies and by other persons in this review process. Final statements (and draft statements if appropriate) shall summarize the significant comments and suggestions made by reviewig organizations and individuals and shall describe the disposition of issues surfaced (i.e., revisions to the proposed action to mitigate anticipated impacts of objections). In particular, they shall address in detail the major issues raised when the Agency position is a variance with recommendations and objections (e.g., reasons why specific comments and suggestions could not be adopted, and factors of overriding importance prohibiting the incorporation of suggestions). Reviewer's statements should be set forth in a "comment" and discussed in a "response."	All comments received during the public comment period which follows proposal of the regulations will be responded to in a separate document.

APPENDIX C

EMISSION SOURCE TEST DATA

The proposed standards of performance for automobile and light-duty truck surface coating operations are based on the use of water-based coating materials in the prime coat, guide coat, and topcoat operations. The numerical emission limits, however, were not developed from actual stack test data. Instead, they were based on determinations of the solvent content of the coating material and the assumption that all the volatile organic compounds (VOC) in the coating material is emitted into the atmosphere through the stacks.

Since two General Motors plants in California and one in Oklahoma are currently operating with water-based coating materials, General Motors was asked to supply EPA with a complete analysis of its coating materials. Other manufacturers and vendors were also asked to supply additional information on the coating materials used in the electrodeposition (EDP) prime system. These sources provided the following type of information; volume percent of each solvent, volume percent total solvent and solids, solvent density, carbon atoms per molecule of solvent, and molecular weight for each solvent. These data were then used to calculate a VOC content using a procedure similar to proposed Reference Method 24 (Candidate 1). Hence, the results from this calculation are the same as those which would have been obtained if coating solids had been tested by proposed Reference Method 24 (Candidate 1). The following equation was then used to calculate the basic VOC emission level corresponding to this coating material.

$$C = \frac{\sum_{i=1}^{n} \left(S_i \quad D_i \quad N_i \quad k/M_i\right)}{V_s}$$

Where:

C = Mass of volatile organic carbon/volume of solid, g/l.

S_i = Percent by volume of solvent component i.

D_i = Density of solvent component i, g/ml.

N_i = Moles of carbon atoms per mole of solvent component i.

M_i = Molecular weight of solvent component i, g/mole.

k = Constant = $12{,}000 \ \frac{\text{g-1}}{\text{mole-1}}$.

V_s = Percent by volume of solids.

In order to give credit for improved coating transfer efficiency, which also reduces emissions, the proposed standards are written in terms of volume of applied solids. Thus, the mass of carbon per unit volume of solids in the coating material, as calculated above, is divided by the weighted average transfer efficiency of the operation. EDP is considered to be 100 percent efficient, while guide coat and topcoat operations range from 40 to 95 percent efficient, depending upon the application method used (see Section 4.2). In calculating the emission levels of the water-based systems, a transfer efficiency of 40 percent was used for the guide coat and topcoat operations.

For the cathodic EDP prime coat material analyses, the procedure outlined above yielded a value of 0.10 kilogram of VOC (measured as mass of carbon) per liter of coating solids. Since the transfer efficiency of an

EDP system is considered to be 100 percent, the computed emissions are 0.26 kilogram of VOC (measured at mass of carbon) per liter of applied coating solids.

The numerical value obtained from an analysis of the General Motors guide coat material was 0.368. Dividing by the 40 percent transfer efficiency for spraying water-based coatings yields a value of 0.92 kilogram of VOC (measured as mass of carbon) per liter of applied coating solids.

Approximately 25 different coating formulations are used in the topcoat operation at the General Motors water-based plants. For the analysis of these materials, General Motors provided one formulation which represented the average of all topcoat formulations. Analysis of this formulation yielded a value of 0.34 kilogram of VOC (measured as total carbon) per liter of coating solids. Dividing by the 40 percent transfer efficiency resulted in predicted emissions of 0.84 kilogram of VOC (measured as total carbon) per liter of applied coating solids.

Although several other factors were considered in the evolution of the emission limits, the values obtained by this procedure were the basis for the numerical emission limits for prime coat and topcoat in the recommended standards. The emission limit for guide coat operations is proposed to be the same as for topcoat operations. Since the guide coat is essentially a topcoat material without pigment, it was decided that, with a transfer of technology, the same emission level could be reached.

APPENDIX D--EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D.1 EMISSION MEASUREMENT METHODS

A. During the emission measurement program, data were collected at the inlet and outlet of a gas-fired thermal incinerator controlling the emissions from a first body coat paint oven. The objective of this test was to evaluate test procedures, as well as to determine the efficiency of the control unit. Two different test methods were used to simultaneously collect the organic compounds emission data. During each test run, three repetitive samples were taken with each test method to provide data for determining the precision of the test procedures. The two test procedures used were:

1. Total Combustion Analysis (TCA).[1]
2. Direct Flame Ionization Analysis.

The sampling apparatus for the TCA method consisted of a stainless steel probe, glass fiber filter,[2] condensate trap, and evacuated gas sample tank. The glass fiber filter was maintained at 250°F and prevented any particulate matter from entering the portion of the sampling apparatus that was later analyzed for gaseous organics. The major portion of the non-methane organics in the effluent was collected in the condensate trap; any non-methane organics which passed the condensate trap were collected in the evacuated tank. Analysis consisted of oxidizing the entire trap contents and a portion of the tank contents (after chromatographic separation of CO, CO_2, and methane) to carbon dioxide followed by quantitative determination with a non-dispersive infrared (NDIR) analyzer. The results were reported as total gaseous non-methane organics (TGNMO) as carbon (ppm C).

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[1] Salo, A.E.; Oaks, W.L.; and MacPhee, R.D., Total Combustion Analysis, Air Pollution Control District, County of Los Angeles (August 1974).

[2] Filter not used in the LAAPCD procedure.

The Flame Ionization Analysis procedure followed during the test program utilized a commercially available flame ionization analyzer to directly measure the gaseous organics from the source after filtration. An integrated bag sample was collected, and the methane content of the effluent was determined by gas chromatography. Total gaseous non-methane organics were quantitatively determined from the total gaseous organics by subtracting the measured methane.

Results[3] of the test program indicated that the concentrations obtained from the flame ionization analysis technique were significantly lower than the concentrations obtained by the TCA methods; this was particularly true at the incinerator outlet. It is known that flame ionization analyzers have a depressed response (compared to methane) for certain species of organic compounds, especially oxygenated compounds. Therefore, it was not surprising that the flame ionization analyzer gave lower results than the TCA method at the incinerator outlet. Due to possible inaccuracies caused by varying response to different carbon species, the flame ionization technique is not considered adequate for use as a reference test method. Therefore, a modification of the TCA procedure has been chosen as the reference method (see Section D.3).

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[3] Emission Test Report: Ford Motor Company, Pico Rivera, California, ESED Report No. 78-ISC-1.

During the test program, one problem was encountered with the application of the TCA method: Although precision at the inlet location was good for all sample runs, very poor precision was obtained for the first five test runs conducted at the outlet sampling location. For these five test runs, it was suspected that the condensate traps being used were slightly contaminated by organics left as a residual from the inlet sampling. Hence, special precautions were taken to assure that during analysis no residual was left in the condensate traps. Improved precision among triplicate samples was obtained for the remaining four test runs at the source outlet. The reference test method (see Section D.3) is a modified version of the procedure used in the emission measurement program and is expected to have improved precision at low emission levels (less than 100 ppm C.).

B. The testing program for the volatile organic content of automotive coatings was limited to evaluating available procedures to determine their applicability to a representative group of coatings.

At the beginning of the program, it was expected that the standard would be expressed in terms of mass of volatile organic compounds per volume of coating excluding water. Industrial and literature sources were consulted for methods to measure the volatile content. There were no procedures that measured this quantity directly, but there were ASTM methods that, when properly combined, could be used to calculate the desired result. The methods that were chosen for evaluation were ASTM D 2369-73, Standard Test Method for Volatile Content of Paints, and ASTM D 1475-60, Standard Test Method for Density of Paint, Varnish, Lacquer, and Related Products. A group of coatings supplied by industrial users were tested for volatile fraction using ASTM D 2369-73. The experimental values were then compared with formulation data supplied by the manufacturer. In general, single determinations showed a great deal of variation, but when the procedure was performed in triplicate and the results averaged, precision improved markedly. Variation between triplicates was always less than 6 percent and, in all cases except one, experimental values were within 6 percent of the theoretical value. The density of the various coatings was measured using ASTM D 1475-60. Since there were no formulation data, no attempt was made to determine the accuracy of the method. By combining the results from the two methods, the mass of volatile organic compounds per volume of solvent can be calculated.

A question remained about the effect of higher temperatures and longer drying times than those specified in ASTM D 2369-73 on the measured volatile organic, particularly for coatings that were normally dried at elevated temperatures. A number of the samples that had already been dried according to ASTM D 2369-73 were heated to 350°F for an additional hour. Most of these samples showed an additional weight loss which was less than 5 percent. However, some samples had an additional weight loss of as much as 30 percent. This was apparently due to the formation of volatile reaction products during the curing of the coating film. Since there are a number of different coatings of this type, each having its own curing procedure, it was decided that for the present there would not be any attempt to measure this additional volatile organic material and the method would limit its scope to the volatile organic contributed by the solvent.

Another question that was raised concerned the measurement of water in water reducible coatings. The standard procedure used by industry is the Karl Fischer titration which was developed to determine the water content of coatings with 1 - 2 percent water. For water based coatings the water content may be as much as 90 percent which is too concentrated for the procedure as written. A modified Karl Fischer procedure was evaluated using a group of water reducible coatings. The experimental values using the modified procedure agreed well with the formulation data but an additional problem remained. Since the final result was to be expressed as the mass of volatile organic compounds per volume of coating excluding water, the water content had to be subtracted from the total volatile mass and volume of coating. Thus relatively small errors in measuring the water content could produce much larger errors in the final result, depending on the relative concentration of water and organic compounds in the solvent. The issue of accurate water measurement and its effect on the volatile organic content determination remains and is currently under study by the ASTM.

To by-pass the question of inaccuracies introduced by the water determination and to make the measurement of VOC content compatible with the method for determining control device efficiency, it was decided to measure the VOC content as equivalent organic carbon per volume of solids. Thus, the standard was changed from mass of volatile organic compounds per volume of coating to mass of organic carbon per volume of solids.

Again there was a search for existing procedures to make this measurement, but there was no single procedure to do this directly. As a starting point, methods to measure the volume of solids in the coating were evaluated. There were only two available methods to measure the volume solids. One was ASTM D 2697-73, Standard Test Method for Volume Non-Volatile Matter in Clear or Pigmented Coating. This procedure measures the volume of a thin paint film by a weight displacement technique. The second method used the ASTM methods already evaluated along with ASTM D 3272-76, Standard Recommended Practice for Vacuum Distillation of Solvents from Solvent-Base Paints for Analysis, to calculate the vol[illegible]. Since the other necessary ASTM methods had already been evaluated and the distillation method produced a clean solvent for the carbon content determination, it was decided to evaluate the latter procedure.

Both solvent reducible and water reducible coatings were distilled using this procedure. After distillation the density of the solvent was determined using ASTM D 1475-60. No problems were encountered distilling the solvent reducible coatings, but there were some problems with the water reducible ones. These coatings foamed on heating, spilling over into the collection flask, and the water in the distilled solvent froze in the collection flask stopping the flow in the delivery line. It was found that the foaming could be eliminated by adding a small amount of inorganic antifoam compound to the sample. An additional collection flask packed in an ice bath and placed in front of the collection flask in dry ice-acetone effectively prevented the frozen delivery line.

As already noted an additional benefit of the distillation technique is that it provided a clean solvent sample which could be analyzed for volatile carbon content. The analysis procedure involved catalytically oxidizing the sample to carbon dioxide which is then measured by a non-dispersive infrared analyzer. Attempts to directly measure the volatile carbon content failed because of volatile losses during sample transfer. However, the VOC content determined from the distilled solvent and compared to the VOC calculated from the formulation data showed very good agreement. For a solvent reducible coating the experimental value averaged about 1 percent lower than the calculated value, while for a water reducible coating the results were about 5 percent lower.

Alternatively, if sufficient formulation data are available, the VOC content per volume of solid can be calculated. The simplest procedure, although not the only one, uses the percent solids by volume and the percent of each solvent constituent by volume to calculate the volatile organic carbon content according to Equation 1.

$$C = \frac{\sum_{i=1}^{n} \left(S_i \; D_i \; N_i \; k/M_i \right)}{V_s}$$

Where:

C = Mass of volatile organic carbon/volume of solid, g/l.

S_i = Percent by volume of solvent component i.

D_i = Density of solvent component i, g/ml.

N_i = Moles of carbon atoms per mole of solvent component i.

M_i = Molecular weight of solvent component i, g/mole.

k = Constant = $12{,}000 \frac{\text{g-l}}{\text{mole-l}}$

V_s = Percent by volume of solids.

This was the procedure used to collect the data on which the standard is based.

It was concluded that the procedures evaluated would be adequate for testing automotive coatings and that their combined results could be expressed as mass of volatile organic carbon per volume of solids.

D.2 MONITORING SYSTEMS AND DEVICES

Since continuous monitoring requirements are not being considered for this industry, discussion of available systems is not applicable.

D.3 PERFORMANCE TEST METHODS

A. "Determination of Total Gaseous Non-methane Organic Emissions as Carbon" (TGNMO) is recommended as the Reference Test Method. The sampling procedures of the reference method are the same as those used in the emission measurement program except for the fact that the reference method does not include a heated filter in the sampling train. Deletion of the filter from the sample train is not expected to alter the sampling results.

The analytical procedure of this method differ from that of the method used in the emission measurement program. In the emission measurement program, the non-methane organics were measured as carbon by oxidizing the non-methane organics to carbon dioxide and subsequently determining the carbon dioxide concentration with a NDIR Analyzer. The Reference Method adds the additional step of reducing to methane the carbon dioxide formed from the oxidation of the organics; a flame ionization detector is used to quantify the methane. This procedure was chosen over the NDIR procedure because an FID is simpler to calibrate and use and has greater sensitivity. Use of the FID, in lieu of the NDIR, for the analytical portion of this method is expected to increase the precision of the test method at low concentration levels (less than 100 ppm as carbon). Since an increase in precision is the only effect expected from this analytical change, the test data collected during the emission measurement program are representative of data which would be collected with the Reference Method.

Although a flame ionization detector is used as the analytical instrument in the Reference Test Method, this method differs greatly from use of a flame ionization detector to directly measure the organics in the source effluent (Direct Flame Ionization Analysis). The procedures of the Reference Method require that the sampled gas first be conditioned by oxidation to carbon dioxide and reduction to methane. Since the flame ionization detector used in the reference method measures all the non-methane organics as methane, all carbon atoms give an equivalent instrument response. Therefore, the problem of varying response ratios for different organic compounds (typical of all flame ionization units) is avoided. The TGNMO method gives a more accurate measurement of total gaseous non-methane organics than the Flame Ionization

Method; this is the primary rationale for recommending the TGNMO test procedure as the Reference Test Method.

B. "Determination of Volatile Content (as Carbon) of Paint, Varnish, Lacquer, or Related Products" is recommended as the Reference Test Method for measuring the volatile content of automotive coatings.

APPENDIX E

ENFORCEMENT ASPECTS

E.1 ENFORCEMENT

The rules and regulations for determining if a source will be subject to new source performance standards by reason that the source is new, modified, or reconstructed, are given in Subpart A, Part 60, Subchapter C, Chapter 1, Title 40, Code of Federal Regulations. It is suggested that interpretation of the foregoing rules and regulations be reviewed through the U.S. Environmental Protection Agency Regional Office Enforcement Division for the region where a source will be located.

The locations and addresses of these regional offices are as follows:

Region I - Connecticut, Maine, Massachusetts, New Hampshire
Rhode Island, Vermont

John F. Kennedy Federal Building
Boston, MA 02203
Telephone: 617-223-7210

Region II - New Jersey, New York, Puerto Rico, Virgin Islands

26 Federal Plaza
New York, NY 10007
Telephone: 212-264-2525

Region III - Delaware, District of Columbia, Maryland,
Pennsylvania, Virginia, West Virginia

Curtis Building
6th and Walnut Streets
Philadelphia, PA 19106
Telephone: 215-597-9814

Region IV - Alabama, Florida, Georgia, Mississippi,
Kentucky, North Carolina, South Carolina,
West Virginia

345 Courtland, N.E.
Atlanta, GA 30308
Telephone: 404-881-4727

Region V - Illinois, Indiana, Michigan, Minnesota,
Ohio, Wisconsin

230 South Dearborn
Chicago, IL 60604
Telephone: 312-353-2000

Region VI - Arkansas, Louisiana, New Mexico, Oklahoma, Texas

First International Building
1201 Elm Street
Dallas, Texas 75270
Telephone: 214-767-2000

Region VII - Iowa, Kansas, Missouri, Nebraska

1735 Baltimore Street
Kansas City, MO 64108
Telephone: 816-374-5493

Region VIII - Colorado, Montana, North Dakota,
South Dakota, Utah, Wyoming

1860 Lincoln Street
Denver, CO 80295
Telephone: 303-837-3895

Region IX - Arizona, California, Hawaii, Nevada, Guam,
American Samoa

215 Fremont Street
San Francisco, CA 94051
Telephone: 415-556-2320

Region X - Washington, Oregon, Idaho, Alaska

1200 Sixth Avenue
Seattle, WA 98101
Telephone: 206-442-1220

E.2 COMPLIANCE

General procedures for compliance testing and emission monitoring are specified in Subpart A, Part 60, Subchapter C, Chapter 1, Title 40, Code of Federal Regulations. Compliance with the proposed emission limits would be determined by the following steps:

1. Determine the average VOC content per liter of coating solids of the prime coat, guide coat, and topcoat materials being used. This would require analyzing all coating materials used in each coating operation using the proposed Reference Method 24 and calculating an average VOC content for each surface coating operation.
2. Select the appropriate transfer efficiency for each surface coating operation from the table included in the standards.
3. Calculate the mass of VOC emissions per volume of applied solids for each surface coating operation by dividing the appropriate average VOC content of the coatings (Step 1) by the transfer efficiency of the surface coating operation (Step 2). If the value obtained is lower than the emission limit included in the standards, the surface coating operation would be in compliance. If the value obtained is higher than the emission limit, add-on VOC emission control would be required to comply with the standards.
4. If add-on emission control is required, calculate the emission reduction efficiency in VOC emissions which is required using the equations included in the standards.
5. In cases where all exhaust gases are not vented to an emission control device, the percentage of total VOC emissions which enter the add-on emission control device would have to be determined by sampling all the stacks and using the equations included in the standards. Representative sampling, however, could be approved by the Administrator, on a case-by-case basis, rather than requiring sampling of all stacks for this determination.

6. The actual efficiency of the control device would be calculated by determining VOC emissions before and after the device using the proposed Reference Method 25.
7. The VOC emission reduction efficiency achieved would be calculated by multiplying the percentage of VOC emissions which enter the add-on VOC emission control device (Step 5) by the add-on control device efficiency (Step 6). If the resulting value of the emission reduction efficiency achieved were greater than that required (Step 4), then the surface coating operation would be in compliance.

Facilities which have achieved compliance without the use of add-on control devices would be monitored by analyzing the coating materials. Increases in the solvent content of coating materials will cause the VOC emissions to increase. Therefore, after the initial compliance determinations have been made, increases in the arithmetic average of the solvent content of all the paints used by a plant would have to be reported to EPA by the plant on a quarterly basis.

Combustion temperatures would be monitored in incineration units which were used to comply with the standard. The initial temperature measurements would be made during compliance testing. Decreases in the combustion temperature in the incinerator would be reported to EPA on a quarterly basis.